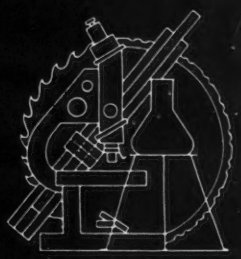
Forest Products Journal



Special Issue

ANNUAL REVIEW

1954 Developments in Major Segments of the Forest Products Industry

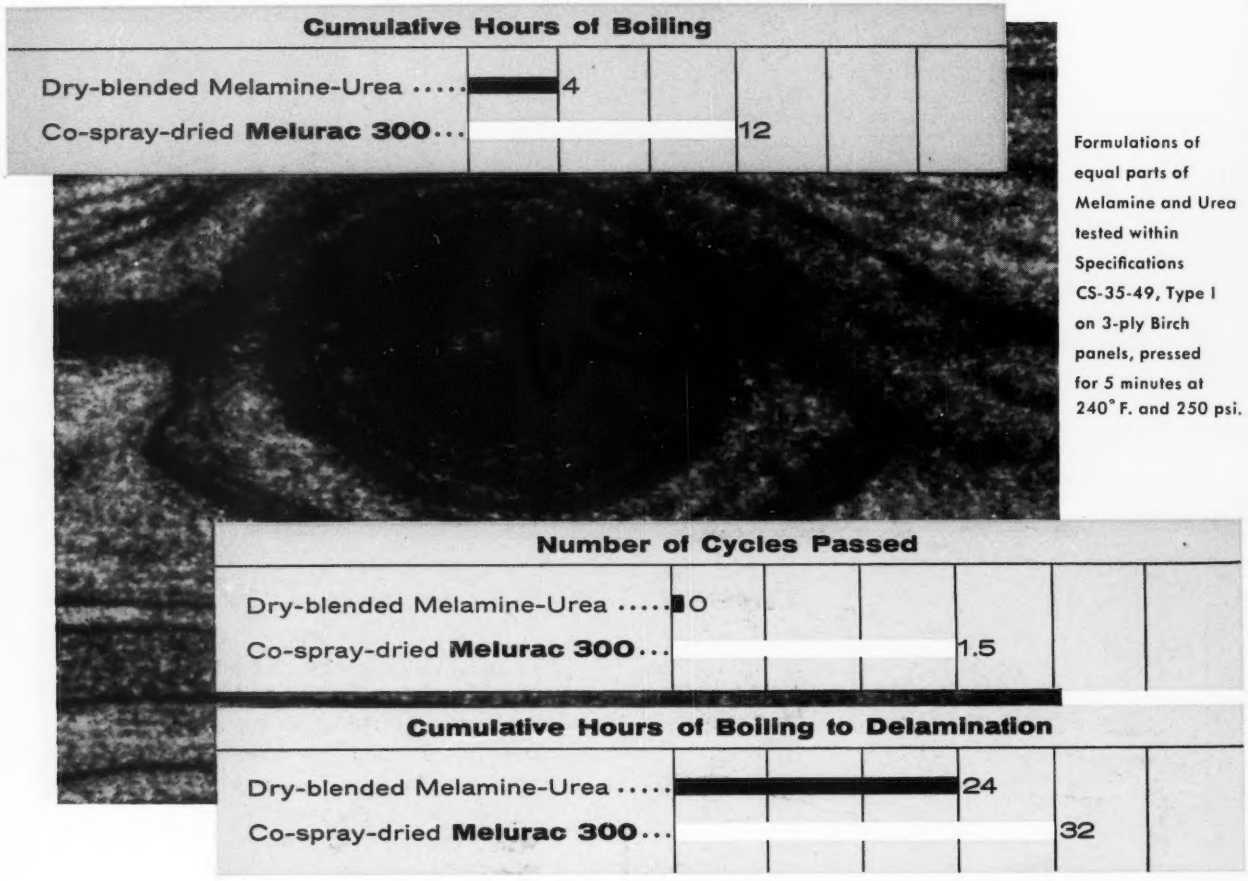
- VENEERS AND PLYWOOD
- WOOD DRYING
- LOGGING
- MILLING
- PACKAGING
- CHEMICAL UTILIZATION
- EDUCATION
- QUALITY CONTROL

Our Wooden Shield

by Hon. George H. Roderick, Assistant Secretary of the Army

Plus 15 Regular Full-length Articles

Published by the FOREST PRODUCTS RESEARCH SOCIETY BOX 2010 MADISON 5, WISCONSIN



Formulations of equal parts of Melamine and Urea tested within Specifications CS-35-49, Type I on 3-ply Birch panels, pressed for 5 minutes at 240° F. and 250 psi.

Eye-opening facts about Melurac® 300

MELURAC® 300 is a co-spray-dried blend of melamine, urea, and formaldehyde. Results of severe boiling and drying tests prove that a co-spray-dried blend is more boil-resistant and durable than a dry blend of the same resins at the same proportions. These results are posted above so you can see for yourself.

In ten years of use, MELURAC 300 has been found ideal for almost all exterior bond applications, including molded plywood boat hulls and exterior hardwood plywood for facing exterior flush doors. It surpasses the exterior test requirements of Commercial Standard CS-35-49.

MELURAC 300 provides a neutral glue line, making possible the pressing of veneers immediately or several days later. It is non-staining and easy to handle. Only water need be added for mixing. Curing temperatures are moderate—from 240°F. to 260°F.—a range which reduces chance of blistering and excessive drying.

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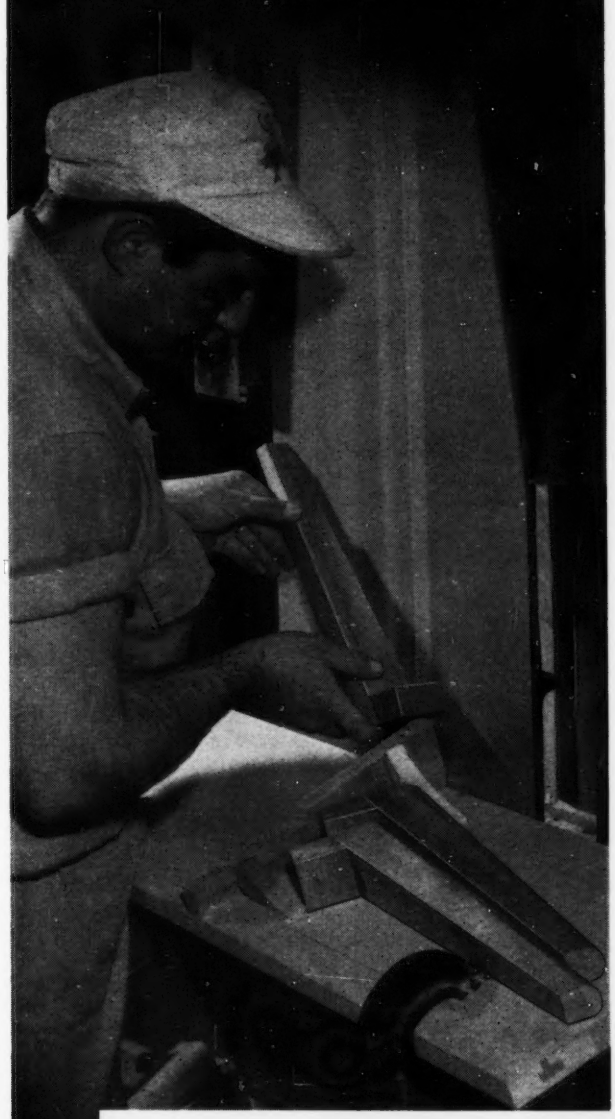

W-3

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Sanding table legs is easy and highly productive with this coated abrasive application. Rugged BEHR-MANNING belts cut cost and produce a flawless finish. If you're faced with a particular finishing problem, why not let a BEHR-MANNING Field Engineer look over the situation. He'll gladly recommend a solution and demonstrate it right in your plant.
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Narrow, flexible cloth belts are favorites for sanding carved surfaces.

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with **RCI GLUES**

1. If you require special glues for special purposes, there's no need to go to a number of different suppliers. Look to Reichhold's wide range of urea-formaldehyde, phenol-formaldehyde, resorcinol, soybean and casein adhesives. You'll find the ones you want for hot press, cold press, R/F, patching, splicing, utilizing wood waste, etc.

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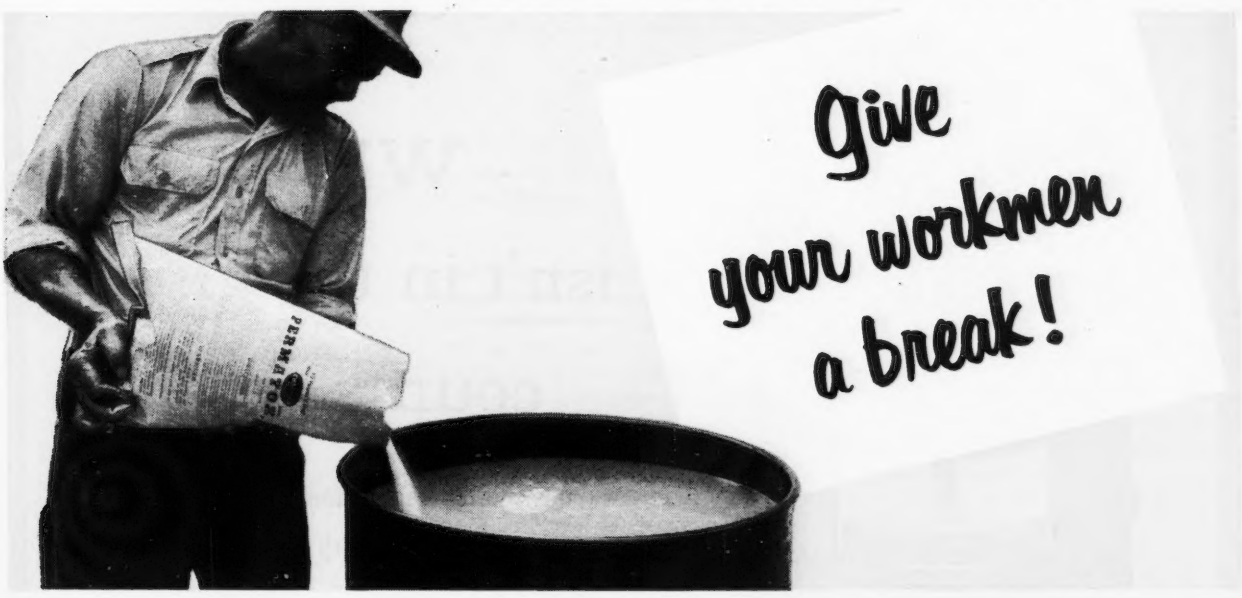


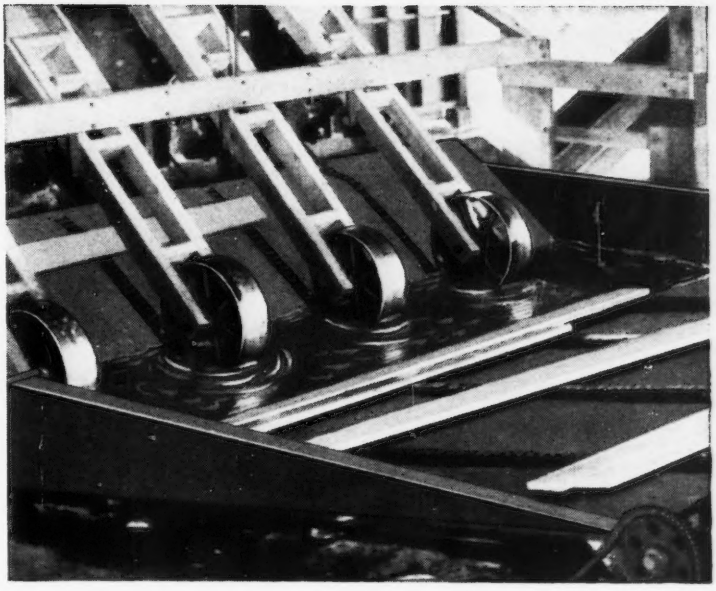
No irritating dust problem with Permatox 10-S

New ingredient makes Permatox 10-S easier to handle and mix than ever before

Since 1933 Chapman has conducted continuous research to improve sap stain chemicals and methods of application. The newest Chapman research development in this field makes Permatox 10-S practically dust-free by the addition of a new ingredient to this tried-and-proven formula.

There is no increase in price for this improved Permatox 10-S.

Permatox 10-S prevents *both* sap stain and mold in hardwoods and softwoods. Mixed with Chapman Ambrocide, it also protects lumber against damaging attacks by ambrosia beetles and other insects.



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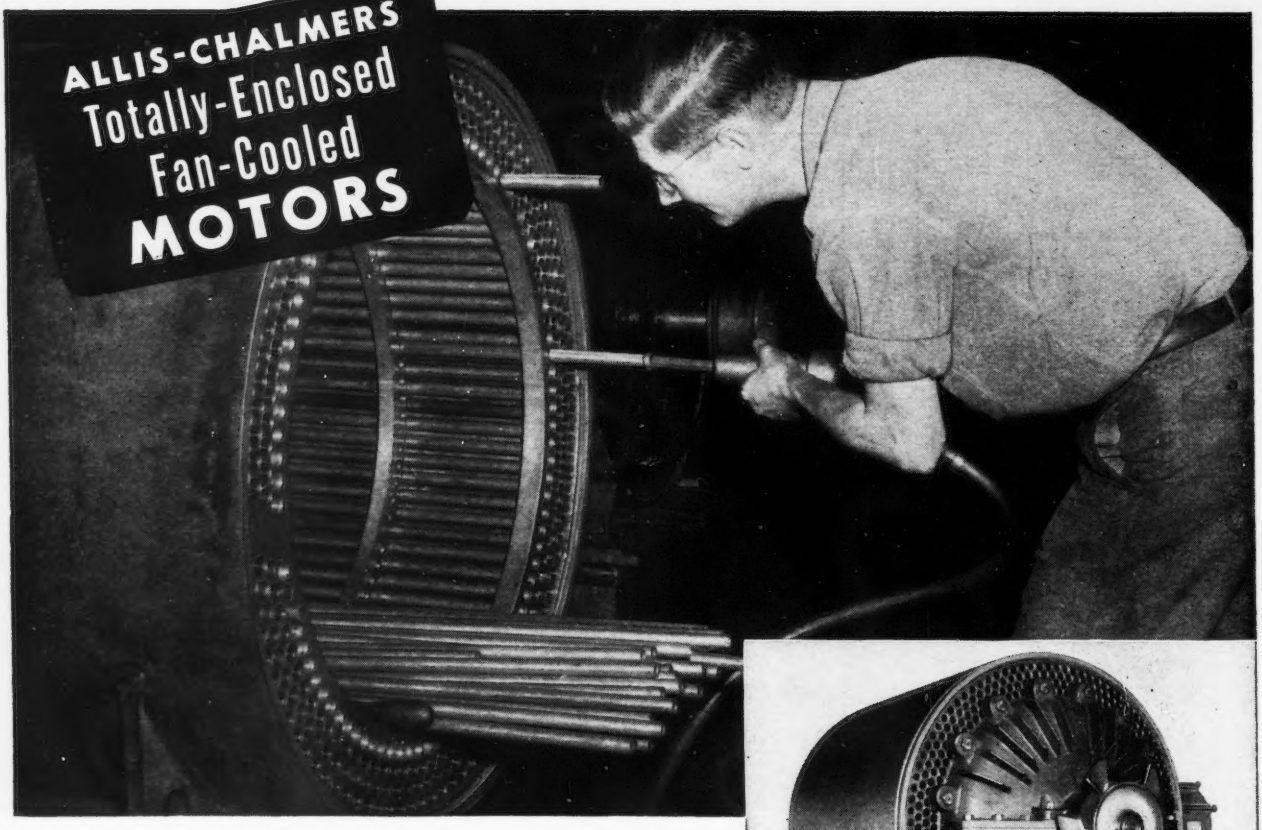

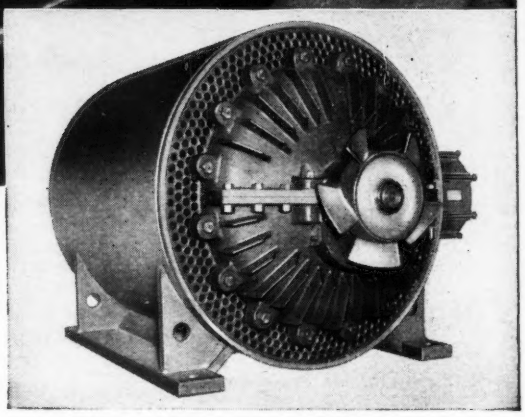

3600-rpm explosion-proof motor with fan housing removed to show unidirectional fan.

These heat exchanger tubes

Protect this motor from dirt and corrosion

COOLING AIR is carried through the heat exchanger tubes with sufficient velocity to expel practically all kinds of dirt. If oily or sticky dirt should cling, tubes can be ramrodded clean on the spot in a few minutes because tubes are straight and tube ends are exposed. Also, the tubes are distributed uniformly around the perimeter of the stator yoke and along its full length — cooling all parts of the motor evenly.

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You can lick corrosion with this motor, too. Tubes are available in a variety of materials to meet practically any corrosive atmospheric condition. Allis-Chalmers tube-type motors have long and successful experience in such difficult applications as caustic plants, refineries and petrochemical plants, power plants with fly ash problems and many others.

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Next time you need a motor for a dirty or corrosive location or for outdoor operation in all kinds of weather, call your Allis-Chalmers District Office. Get complete information on Allis-Chalmers tube-type totally-enclosed, fan-cooled and explosion-proof motors. Or write Allis-Chalmers, Milwaukee 1, Wisconsin, for Bulletin 51B7149. Available in ratings on frames larger than NEMA 505 up to 3000 hp.

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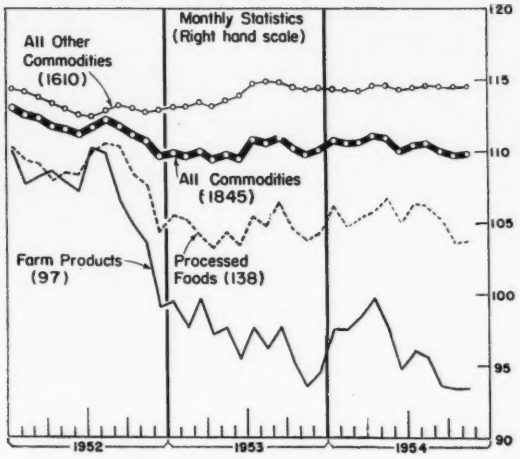
ALLIS-CHALMERS

FPRS NEWS-DIGEST

Volume 5 FEBRUARY, 1955 Number 2

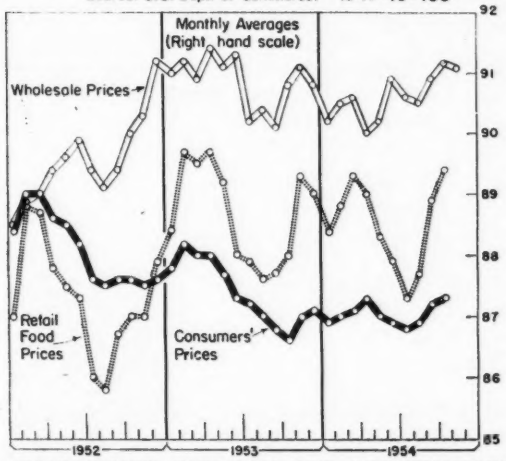
WHOLESALE PRICE INDEXES

1947-49 = 100 (Revised Series)
Source: U.S. Bureau of Labor Statistics

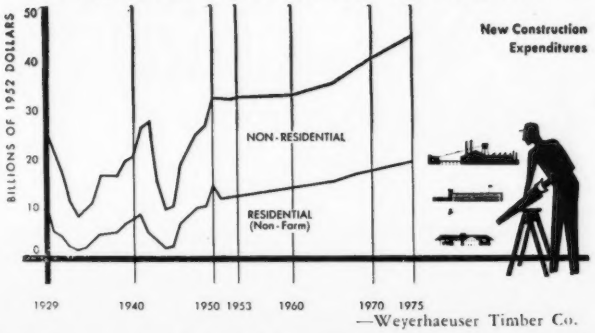


PURCHASING POWER OF DOLLAR

As measured by Wholesale Prices, Consumers' Prices, and Retail Food Prices
Source: U.S. Dept. of Commerce. 1947-49 = 100



LONG-RANGE OUTLOOK FOR CONSTRUCTION



—Weyerhaeuser Timber Co.

BUSINESS OUTLOOK

CONSTRUCTION BOOM in 1955 is indicated by January outlays of $2.8 billion, up 13% from 1954 and new high for month. Public works held even, private building jumped 18½%. Home building contributed $1 billion to January total, 30% ahead of last year. Prospects for rest of year are decidedly hopeful. F. W. Dodge Corp. lists home awards in 37 states east of Rockies 49% ahead of year ago.

—Business Week, Feb. 12.

ENGLAND HAS LET DOWN BARS, will permit importation in 1955 of between 80 and 100 million feet of U.S. hardwoods, according to Chester B. Stem, Inc. Whole European economy is strengthening, hardwood requirements of other countries are accelerating. This means hardwood lumber prices will firm and possibly increase.

AMERICA'S NEXT GREAT ECONOMIC ADVANCE must depend not so much on mass production as on new products developed by our research laboratories, according to Roy C. Ingersoll, president of Borg-Warner Corp. He told Industrial Research Corp. in Chicago that other nations have developed mass production art; our margin of economic superiority will shrink as they catch up on production and invade more world markets.

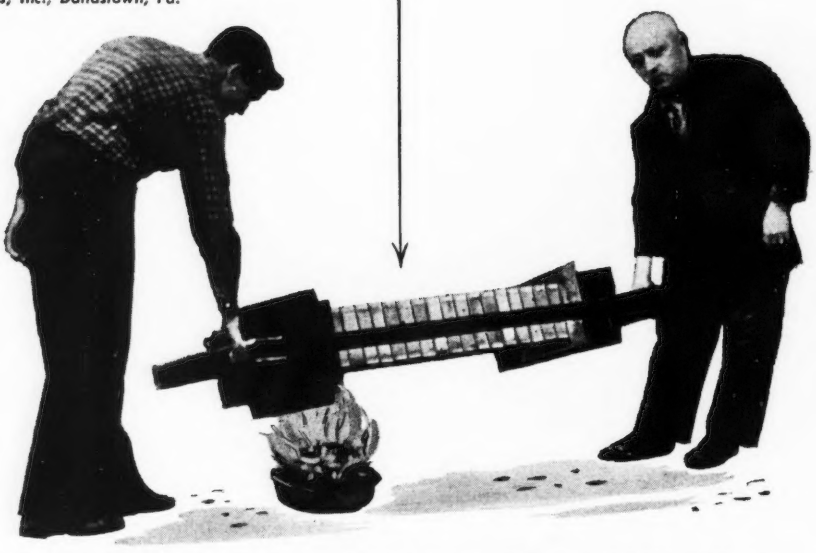
—Business Week.

DOUGLAS FIR PLYWOOD industry is off to good start in '55—first week production jumped 16% over same '54 week. Industry is shooting for record 4.2 billion feet sales this year. '54 sales climbed to 3.8 billion peak, 4% ahead of '53 high.

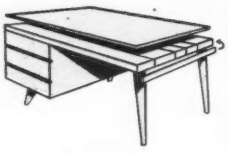
—Veneer Newsletter.

WHAT CENTURY IS YOUR GLUING OPERATION IN?

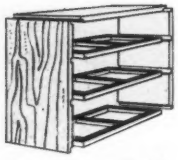
Thermatron installation at Guy Hobbs, Inc., Dallastown, Pa.



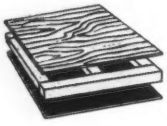
Just as their medieval ancestors used to do, this master carpenter and his assistant photographed recently in front of their shop in Sorrento, Italy, are engaged in slowly moving a rack of freshly glued wooden boxes back and forth over a fire. When the glue sets, the boxes will be ready for their leather covering.



Core stock for desk, chopping blocks, etc.



Case clamp assembly of dresser, book case or cabinet.



Panel on frame doors, cabinets or furniture.

Today's production pace calls for nothing less than THERMATRON high frequency wood bonding.

Don't smile at the pace and antique methods of these gentlemen. Even today in your modern high-production shop the wood bonding operation may remain pretty much the way it was in grandfather's day . . . Yet it doesn't *have* to.

Have *you* seen how THERMATRON high frequency generators, presses and other equipment bond wood in seconds instead of hours? Have *you* seen how THERMATRON slashes production costs, eliminates rejects, permits parts inventory reduction and frees valuable plant space for more profitable uses?

Write or phone today for literature and full particulars regarding a THERMATRON installation in *your* plant . . . No obligation, of course; just address Section FP-3.

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INDUSTRY NEWS

Meeting Future Wood Demand Discussed at APA Meeting

Three ways to meet America's increasing demand for wood were scheduled for discussion at the American Pulpwood Association's annual meeting in New York City February 23. "The Next Fifty Years" was the day's theme.

First scheduled speaker was A. Kenneth Beggs, senior economist of the Stanford Research Institute, reporting the nature and size of the demand. He directed a recent study by his organization for the Weyerhaeuser Timber Co. which included an estimate of timber consumption through 1975. (See *Journal of FPRS*, October 1954)

Other speakers discussed these broad ways to anticipate this demand: closer utilization of trees cut, increased use of hardwoods, and more intensive forest management.

Oregon Forest Products Lab Reports on 1954 Studies

The Oregon Forest Products Laboratory engaged in 26 major projects to develop and improve products and markets for the timber industry during 1954, according to OFPL *Laboratory Notes*. Nineteen reports have been published on results of completed research and 13 more are being prepared for publication.

The projects included studies of extractives from Douglas-fir bark, manufactured products from wood residues, testing of wood roof and wall diaphragms, vapor-drying, and western hardwood utilization.

Tenth Northwest Wood Products Clinic Meets in April

Final plans are being made for the tenth annual meeting of the Northwest Wood Products Clinic, according to Everett Ellis, Secretary–Treasurer. The meeting will be held April 19 and 20 at the Davenport Hotel, Spokane, Wash.

The program committee includes: H. W. Russell, Russell & Pugh Lumber Co., chairman; Dr. George Marra, Washington State Institute of Technology; Hugo Schmidt, J. Neils Lumber Co.; M. E. Jones, Potlach Forests, Inc.; and Ellis.

Wood Working Digest Award of Merit Contest Closes March 31

A third division has been announced for entries in the second annual Wood Working Digest Award of Merit contest. Schools of forestry and other educational institutions are covered in the new group, joining the divisions of associations and companies.

March 31 is the contest closing date. Winners will be announced and awards made at the National Annual Meeting of FPRS in Seattle in June. Each winner will receive a scroll, printed on German parchment, hand finished, and mounted on a solid walnut base with a recessed glass face.

Further information and official entry blanks may be obtained from Contest Dept., Wood Working Digest, 222 East Willow Ave., Wheaton, Ill.

North Carolina Proposes New Industrial Experimental Program

Research to find new uses for wood wastes in production of chemicals is among three projects related to forest products in a proposed industrial experimental program at the North Carolina State School of Engineering. The school suggests seeking additional uses for tannin extracted from pine bark and for the wasted lignin and cellulosic materials resulting from the extraction process.

A second study proposes determining methods of utilizing North Carolina hardwoods and maintaining dimensional tolerances for furniture manufacture. The program also would include seeking methods and processes by which pine extract can be used to control corrosion in boiler tubes and condensate return lines. The latter would aid in preventing corrosion in public water supplies.

The three projects are among five to be covered in the first two-year study period if the state's General Assembly approves the program.—*Statelog*.

Minnesota Completes Study on Preservatives for Greenhouse Use

Researchers at the University of Minnesota School of Forestry have proven that copper naphthenate is a safe preservative for treating lumber used in greenhouse benches, flats, and trays. Results of the four-year study were announced this month by Frank H. Kaufert, school director, and K. A. Loerch, former graduate student.

Other standard wood preservatives tested were found to be too poisonous to greenhouse plants, Kaufert and Loerch report. They say that thorough treatment with preservatives by vacuum or pressure processes is best, but that increased service life can also be obtained by soaking pre-cut lumber in a 15 per cent solution of copper naphthenate.

Complete test results are given in a Minnesota Forestry Note, obtainable free from the School of Forestry, Institute of Agriculture, University of Minnesota, St. Paul 1.

South's First Slab Debarking Plant Operating in Alabama

The first slab concentration yard and slab debarking and chipping plant in the South may result in wholesale recovery of pulpwood chips from sawmill leftovers in a wide area. The yard, operated by Clancy Forest Products Co., Inc., Decatur, Ala., reportedly can handle full production of slabs and edgings from mills up to 75 miles away.

Feature of the operation is a new hydraulic slab debarker which can handle slabs up to 16 inches wide and 8 inches thick. Bark is cleaned from slabs and edgings by two water jets normally operated at 900 psi. The pressure can be adjusted to meet varying bark adhesive qualities. Streams from the jets form a solid sheet of water striking the slabs at a 30 degree angle. Removal of bark around knots is satisfactory and wood fiber loss is negligible, it is reported.

The plant is converting slabs and edgings into bark-free chips at an average rate of 300 cords per week. The chips are shipped by barge to the Bowaters Southern Paper Corp. plant at Calhoun, Tenn. Analysis at the mill indicates an average of less than 1 per cent, by weight, of bark in each ton of chips.

Hardwood Utilization Study Scheduled in Georgia

Utilization and management of Piedmont hardwoods will be studied in a new research project centered at the School of Forestry, University of Georgia, Athens. The project will be directed by the Southeastern Forest Experiment Station and financed by a $175,000 grant to the U. S. Forest Service.

Purposes of the study are to find new markets, improve utilization of low-grade and little-used hardwoods, improve management procedures, and determine causes and prevention of prevalent defects.

Dr. W. A. Campbell, research associate at the forestry school, will be in charge of the study. The staff will include five utilization specialists, one wood technologist or one forest pathologist, and seven management specialists.

Waste Utilization Equipment Emphasized by APA Committee

Sawmill waste utilization equipment was discussed at a recent meeting in Jacksonville, Fla. of the Southeast Technical Committee, American Pulpwood Assoc. The two-day meeting included an equipment demonstration on

This advertisement appeared in
BUSINESS WEEK—August 21, 1954

DESIGNED AND BUILT BY CENTRAL-LAMSON CORP., YAKIMA, WASH.

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Here's another smart use of wood as a low cost, high-strength structural material offering light weight, easy fabrication with quickly trained help and inexpensive fixtures . . . and fast assembly with Borden's waterproof resorcin resin glues.

Let a good wood engineer look at the construction you're now planning. And let Borden's advise you on how to glue it. Address: The Borden Company, Chemical Division, Dept. FP-25, 350 Madison Avenue, New York 17, New York.

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THE *Borden* COMPANY
CHEMICAL DIVISION

a forest area of the St. Regis Paper Co.

Speakers discussed recent developments in log debarkers, a hydraulic slab debarker, waste wood chippers, and chip handling systems. Also covered were the four phases of the association's technical review program—woods preparation, hauling and handling, safety training and supervision, and industrial forestry.

Further information may be obtained from the American Pulpwood Association, 220 East 42nd St., New York 17.

Nominations for TECO Scholarships Due March 15

March 15 is the closing date for four special student scholarships being awarded by the National Lumber Manufacturers Assoc., according to an announcement by Leo V. Bodine, NLMA Executive Vice-President. Winners will be announced April 15.

The scholarships enable students in wood utilization or wood technology to receive ten weeks' summer training at Timber Engineering Co. laboratories, Washington, D. C. Each winner will receive a cash grant of $500, plus travel expenses.

Southern Hardwood Producers Meet in New Orleans March 10–11

National and local topics of interest to hardwood manufacturers will be featured at the annual meeting of the Southern Hardwood Producers, Inc., it is announced by L. J. Heatherly, Secretary–Manager. The meeting will be held in New Orleans on March 10 and 11. The National Lumber Exporters Assoc., meeting in conjunction with SHPI, will convene March 9.

A highlight of the meeting will be the third annual presentation of the "Hardwood Industry Man-of-the-Year" award. Previous winners of the award were: John B. Veach, president of Hardwood Corporation of America, Asheville, N. C.; and Lee Robinson, Mobile River Saw Mill Co., Mt. Vernon, Ala.

Record Increase in Tree Farms Noted in 1954

The industry-sponsored American tree farm system reported the greatest progress in its 14-year history during 1954. A total of 3,573,708 acres were brought into the system during the year, bringing the tree farm acreage up to 33,692,964.

In announcing the increase, James C. McClellan, chief forester for American Forest Products Industries, predicted five million acres would be added to the system in 1955. AFPI is national coordinator of the program.

Leading states in the program are Texas, 3,429,363 acres; Washington, 3,259,806; Oregon, 3,231,388; and Arkansas 3,136,948. Tree farm programs are now underway in 36 states, with 4 more expected to enroll in 1955. The annual farm woodlot harvest in the U. S. is estimated at $700 million.

Georgia's Forests Shift From Large to Small Timber

A change in Georgia's forest resources from large to small timber is indicated by a recent forest survey report by the Southeastern Forest Experiment Station. Although total pine timber volume is only 2 per cent less than in 1936, sawtimber volume has decreased 13 per cent, according to the report.

Pulpwood production jumped from 200,000 cords in 1937 to 2,500,000 in 1952. Looking toward the future, the number of young pines has increased 41 per cent—enough to stock 1,500,000 acres. More than 2,500,000 acres in excess of land clearing has been added to the state's forest area since 1936, through abandoned farm land reverting to forest.—*What's Happening in Forestry.*

SOCIETY NEWS

National Meeting Dates Changed to June 21–24

Dates for the FPRS Ninth National Annual Meeting at Seattle have been set back one day later than originally scheduled, according to John D. Ritchie, general chairman. The revised dates are June 21–24.

"This change in program was made to enable some FPRS members associated with the plywood industry to attend portions of the Douglas Fir Plywood Association's Golden Jubilee meeting in Portland, Ore., June 21–23," Ritchie said.

Registration for the FPRS meeting will take place in the Olympic Hotel from 1:00–8:00 p.m., Monday, June 20. The revised program of technical discussions will fill the following three days.

Technical sessions have been scheduled on the subjects of composition boards, wood drying, logging and milling, wood preservation, packaging, veneer and plywood, chemical utilization, glues and gluing, marketing, wood finishing, and wood machining. Special tours of various wood manufacturing plants in the Seattle area will also be arranged.

A highlight of the entertainment program will be a Potlatch on the shore of beautiful Hoods Canal, Twanoh State Park, on Thursday evening, June 23. The Potlatch is an Indian ritual that includes native dances and a feast of barbecued salmon. The attendees will leave Seattle by bus, take a ferry trip to Bremerton and tour the Navy yard there, and then proceed to the park. The party will be staged by various suppliers.

A full day tour of the wood products manufacturing plants in Everett, Wash., is planned for Friday, June 24, final day of the meeting. Special trips to other plants in Washington and Oregon will be arranged for attendees desiring to spend time in the Pacific Northwest following the meeting.

An entertainment program for wives and children is also being planned. Trips to points of interest in the Seattle area are scheduled along with informal meetings.

President Carr Will Address Ottawa Meeting

President Lester J. Carr will be among opening day speakers at the Eastern Canadian Section annual meeting at Chateau Laurier, Ottawa, in March. Executive Secretary Frank J. Rovsek will also attend the meeting, to be held March 14–16.

Principal discussion topics at the March 14 session will be furniture technology and timber fabrication. Present and future problems of timber as a structural material will be a panel subject, and the new TECO film, "Engineered Timber Construction," will be shown.

Col. J. H. Jenkins, Chief of the Canadian Forest Products Laboratories, will be chairman of the March 15 session. Papers will be presented on sawing efficiency, material handling in the furniture industry, Canadian standards for softwood lumber, stiffness factors in plywood construction, and high speed photography in wood machining research. A panel will discuss the relationship of various governmental research agencies in Canada.

The meeting will close March 16 with a tour of Ottawa, emphasizing the federal planning program.

Ten Universities Represented By "Wood Award" Entries

The 1955 "Wood and Wood Products Award" has drawn indication of 15 entries from 10 universities throughout the U. S. and Canada as of February 15. The contest is being sponsored for the sixth year by Vance Publishing Company, Chicago, publishers of Wood and Wood Products magazine.

March 25 is the final deadline for submission of tentative titles, and entries must be submitted by May 10. Complete rules may be obtained from the Executive Secretary, FPRS, Box 2010, University Station, Madison 5,

WHO'S WHO among men who know glues*

STEPHEN K. SMITH
Lane Company of Tennessee, Inc.

Stephen K. Smith, plant manager of the Lane Company of Tennessee, Inc., knows glues and he knows woods, too—both academically and practically.

He majored in Wood Utilization at New York State College of Forestry, then underwent a course of post graduate work in wood and any other available concealment utilization through Guam, Leyte, Ie Shima and Okinawa, as a U.S. Infantryman! He is still in the Active Reserve!

In March of 1946, he joined the makers of famed Lane Cedar Chests and Lane Tables, where for eight and one-half years he has devoted himself progressively to the perfection of the Lane Company's masterful utilization of wood in their fine products for the home.

Mr. Smith is married—and there's a 7-year old Stephen K. Smith, Jr. who, in view of his father's inherent interest in wood and its uses would naturally have to be nicknamed "Chip"!

HARRY C. BERNICCHI
W. W. Kimball Company

Who would think that a glue failure in a single unit in one of those fine pianos for which the W. W. Kimball Company has an international reputation could mar a symphony orchestra's otherwise masterful rendition of a Brahms concerto.

Harry C. Bernicchi, Superintendent of the Mills and Plycor Division of the W. W. Kimball Company, Chicago, has spent 24 years in 14 varied departments of fine piano building. For the past 12 years he has been vitally interested in glues and their performance.

It was the W. W. Kimball Company that first discovered the possibilities of the right type of veneered panels in their "Life Crown Tone Board." Also for laminated pin blocks, another Kimball first—and another opportunity for the development of the right glue for a job on which the tonal triumph of a concert may depend.

Mr. Bernicchi is married and the father of two daughters.

Do you realize just how many really vital glue jobs there are—from laminating intricate panels for fine musical instruments to giant trusses to support a roof? Is it any wonder that we of National Casein take so seriously this job of delivering the right glue for your job—where you want it, when you want it, and how you want it—tank car, tank truck, drum or bag!

Purpose of our series on "Men Who Know Glues" *is to stimulate our own and your thinking on the subject of glues as well as to remind you that you'll stick with National Casein glues—because they stick for you.*

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Wis., or the sponsors, Wood and Wood Products magazine, 139 N. Clark St., Chicago.

Prizes consist of $350 for the best graduate paper and $150 for the best undergraduate paper on any phase of forest products. The awards are administered by the FPRS education committee and will be presented at the National Meeting in Seattle in June. The contest is open to all students in North American colleges or universities who have been enrolled for at least one quarter or semester between May 1, 1954, and April 30, 1955.

Everett Ellis, University of Idaho, is chairman of the undergraduate paper judges. The graduate paper judges will be: Robert Blumenstein, TECO, chairman; Harold C. Moser, Gamble Bros.; and William T. Nearn, Pennsylvania State University.

The following schools have indicated entries to date: University of Minnesota, Rensselaer Poly. Inst., U. of Michigan, N. C. State, State University of New York, Alabama Poly. Inst., Cornell University, U. of Wisconsin, Yale University, and U. of British Columbia.

Midwest Section Plans Spring Meeting in Illinois

Plans are being completed for the spring meeting of the Midwest Section at Champaign–Urbana, Ill., April 11 and 12, according to Wayne C. Lewis, section chairman. Profs. Charles S. Walters and William A. Oliver are arranging the program.

"Forest Products in Today's Homes" will be the theme of the meeting, which will include a half-day "show-me" trip to the Illinois Small Homes Council. The program will include papers on the Retail Lumber Dealers Research Council program, use of glue as structural connectors in housing, considerations needed for wood to compete with other materials in farm buildings, commercial standards for sash and doors, wood in furniture design, and possibilities for hardwood paneling for small manufacturers.

The spring meeting will be the first held in the southern area of the Midwest Section, previous sessions having been in Chicago or Madison. Section officers plan to hold frequent meetings in the area if enough interest is demonstrated at the April meeting, Lewis reports.

G–A–F Section Plans Action Program in 1955

A four point program for 1955 is planned by the Georgia–Alabama–Florida Section. It includes: stimulating more interest in FPRS among forest products industries of the region, an active program to increase and improve the use of wood products in a selected specified field, spring meeting in Savannah area in addition to annual meeting in Gainesville, Fla., and continued campaign for new members.

Officers for 1954–55 elected at the recent annual meeting were: Boyd Richards, chairman; Windell Vickery, sec.-treas.; and Harley Langdale, Jr., Julian McGowin, Spain Willingham, J. A. Greenwald, Guy H. Wesley, and Gus Jacobson, trustees.

The meeting program included eight papers by representatives of various industrial firms, research groups, and educational institutions. A guided tour of the Alabama Polytechnic Institute Experiment Station was a highlight. Local arrangements were made by Prof. W. B. DeVall and his staff.

Northeast Section Announces Program for Spring Meeting

Three technical sessions and field trips to nearby forest properties and industries will be features of the spring meeting of the Northeast Section. Chairman Charles Lockard will preside at the meeting April 28 and 29 at the Queensbury Hotel, Glens Falls, N. Y.

"Making the Most of Our Sawmills" will be the subject of the opening technical session on April 28. Norman C. Bye, Director of Engineering, Henry Disston & Sons, will serve as chairman. Scheduled speakers are: Siegfried W. Tolle, Northeast Wood Products; Prof. K. C. Compton, N. Y. College of Forestry; Myron D. Ostrander, Northeastern Forest Exp. Sta.; and C. D. Kingsbury, Supt. of N. Y. state forests.

Chippers and bolters will be demonstrated on a half-day field trip to the Syracuse forestry college's Pack Demonstration Forest, Warrensburg. Members attending will tour the forest and inspect permanent sawmill facilities.

Dean Hardy L. Shirley of the N. Y. College of Forestry will be principal speaker at the section's annual dinner. Chairman Lockard will be toastmaster.

Discussions on seasoning, machining, research, milling, and waste utilization will comprise the second technical session on "Something for Everyone". Section leaders will be J. Harry Rich, Robert J. Hoyle, Jr., Richard N. Jorgenson, Fred C. Simmons, and J. Allan Hauter.

Donald F. Pierce, Maine Dowel Co., will preside at the final session on "Special Products Operations." Speakers will include Herbert O. Fleischer, U. S. Forest Products Lab.; F. W. O'Neil, N. Y. College of Forestry; and John Tebbetts, Ecko Tebbetts. The meeting will close with the annual business session, followed by optional trips to plants holding open house.

Regional and National Nominating Committees

President Lester J. Carr has announced selection of two regional committees to nominate candidates for the FPRS Executive Board. National officer candidates for 1956 will be named by the National Nominating Committee. The officers and regional board members will be elected by mail ballot, and results announced at the National Meeting in Seattle June 21–24.

The national committee will nominate at least one eligible member for president-elect, one for vice-president, and at least eight members for the 1957 fiscal year national nominating committee.

The regional committees were chosen by President Carr after consultation with section officers. They will nominate candidates to succeed Dr. J. A. Hall, North Central, and Ray E. Shreck, Southwest, whose three-year terms are expiring.

The National Nominating Committee consists of Ken G. Chesley, chairman; A. B. Anderson, Roy M. Carter, George G. Marra, H. B. McKean, and Fred F. Wangaard.

The regional committees include: North Central—Ralph Casselman, chairman; Robert Dosker, Forrest Beil, Stephen Pryce, and Howard Olson; Southwest—L. N. Ericksen, N. Thomas Shelton, William VanBeckum, Harris Vaughan, and Theodore Combs.

Pacific Northwest Section Awards 15 Student Memberships

The Pacific Northwest Section is again awarding FPRS student memberships to five students at each of the three forestry schools in the section, according to Walter C. Ring, chairman.

J. W. Wilson, chairman of faculty committee on awards, University of British Columbia, announced winners there were: W. V. Hancock, B. Kelly, S. Kun, E. B. Marstrand, and D. H. Patrick.

Winners at the School of Forestry, Oregon State College, announced by Dean W. F. McCulloch, were: E. F. McDade, R. F. McCormick, C. P. Farnham, J. T. Patterson, and T. L. Twedt.

The College of Forestry, University of Washington, has not announced selection of winning students there.

Warren Elected Chairman Of Inland Empire Section

Cameron J. Warren was elected chairman of the Inland Empire Section at the annual meeting January 21 in Yakima, Wash. He is vice-president of the International Lumber Co., Missoula, Mont.

Other officers elected were: E. C.

(Continued on page 37A)

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Where the Money Goes

SACRAMENTO—I feel it appropriate, as we approach a new FPRS year, to discuss with you the financial aspect of our Society—where we get our income, and more important, where we spend it. FPRS operates on the theory that each fiscal year it will return in services to its members or the industry close to 100 per cent of its income. We are not accumulating reserves beyond a modest amount, roughly $1,000 per year, which is being invested in the erection of a national executive office building.

L. J. Carr

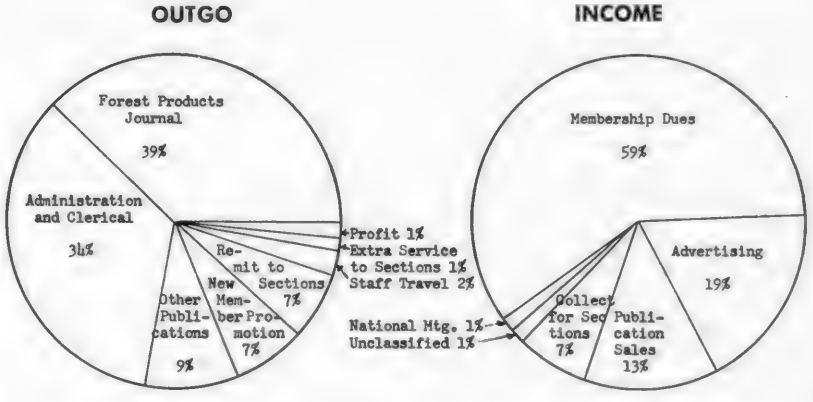
The charts below tell the story. They give the breakdown of income and expense for the fiscal year ended last March 31. They show that we have maintained a balanced budget while at the same time giving our members a sensible return in service for their investment.

income grows, you may confidently expect to see more issues of the JOURNAL, more helpful articles, more services through the executive office.

Our largest expenses are publications, 39 per cent, and administration, 34 per cent. The latter includes the bulk of our staff salaries, overhead and rent. Again, as both income and membership increase, this ratio will spread toward a higher percentage for publishing and relatively less for administration.

Since 1947 we have saved, as reserve, almost $10,000. This is invested in a choice building site on which we hope with your help to erect a modest but permanent executive office building during 1955. Complete details were given you in January. It is hard to realize that eight years ago our Society was but an idea in the minds of a handful of visionary men. Our growth is a fitting tribute to their faith.

A final comparison is in order. Based on a program of service to its members



Let's look at the figures. The principal sources of income were 59 per cent from dues and 19 per cent from advertising. This compares with a similar but older society than FPRS which derives 72 per cent through membership and 19.5 per cent through advertising. With continued growth of the JOURNAL this ratio will swing in future years to a higher percentage in advertising and relatively less in dues. This is properly so, because our JOURNAL fills a definite need for certain types of information, while at the same time reaching a very select and progressive audience. It enjoys a "natural" appeal among advertisers. Thus, as our Society spent $25.76 per member last year. That's a full $10.00 more than the cost of an individual membership and two times that spent by a parallel society, and is made possible thanks to our 100 Company supporting members and many advertisers! In my book, the service we are getting, in publications, meetings, and personal attention is something to be proud of.

A society is like the automotive industry—the bigger it gets, the better the values it makes possible for its customers. Remember that the next time you meet a wood industry man who is not a member of FPRS.

—L. J. CARR, *President*

IMPORTANT FPRS DATES

February 28–March 1: Pacific Northwest Section Meeting at Seattle, Wash.

March 14–16: Eastern Canadian Section Annual Meeting at Chateau Laurier, Ottawa.

March 17–18: Executive Board Meeting at Madison, Wis.

April 11–12: Midwest Section Meeting at Champaign–Urbana, Ill.

April 28–29: Northeast Section Annual Meeting at Glens Falls, N. Y.

May 13: Ohio Valley Section Meeting.

June 21–24: 1955 NATIONAL MEETING at Seattle, Wash.

June: Pacific Southwest Section Meeting at Los Angeles, Calif.

Nov. 7–8: Mid-South Section Meeting at Memphis, Tenn.

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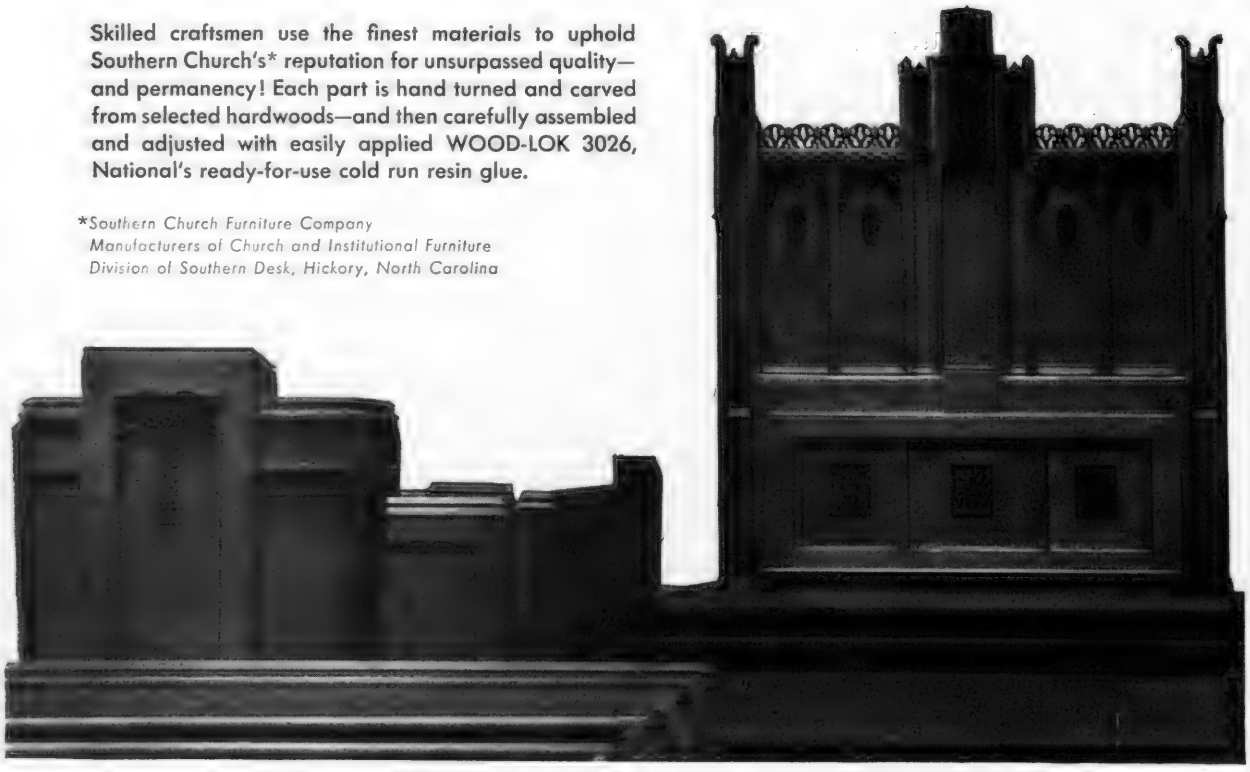

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Our Wooden Shield

HON. GEORGE H. RODERICK

Assistant Secretary of the Army. Formerly Vice-President, American Seating Company

U. S. Army Photo

THE BATTLESHIPS versus Bombers controversy of its day took place in Greece a long time ago when people were looking for ways to cope with the Persian menace. Finally, they decided to buck it up to the higher echelons and consulted the local Oracle, an Assistant Secretary of those times.

The Oracle calmly told them to build "wooden walls." That was an unusually satisfactory policy declaration, since for two thousand years no one has been able to decide just what it meant. A wooden Maginot Line or a bigger fleet? It so happened that at the moment the Battleships school had better public relations and was able to win the appropriation; but that, for me, is not the crux of the story. What interests me is that whichever way you look at it, then as now, *wood* was in the country's first line of defense.

A simple statistic will suffice to prove the truth of this proposition for us today: The American armed forces consumed *seventy billion board feet* of wood products in winning World War II!

Research Importance Is Incalculable

The most spectacular use of wood in wartime is of course in packaging. After all, everything that the Army uses must be shipped to the theater of operations and arrive there in fighting shape. In the peak year of World War II, half of the entire lumber production of the United States—17 billion out of 34 billion board feet—went into packaging and crating for the Armed Services! The importance of research in this picture is almost incalculable. An idea of it is given in the fact that wartime applied research (based on earlier fundamental research) made it possible for the same cargo that had required five ships in 1941 to be carried across the ocean in *four* by 1945. At the end of the war a fifth of our cargo fleet, the lifeline of the western alliance, had in effect been given to us by forest product research.

Increasing use of air transportation faces us with similar challenges, which are being met. For instance, we are pushing the use of paper overlay veneer, which is 20% cheaper than plywood, as a crating material; developing wirebound and paperboard boxes that are lighter and stronger than old types; and constantly experimenting with cleating patterns. This knowledge, and the lessons learned from undertakings like the Berlin airlift, will be applicable to military and civilian operations alike.

An interesting example of highly specialized wood research was the Army's attempt to develop a non-metallic land mine, which would be much harder to detect than the metal types. The Government worked on this device in cooperation with several private firms, including the company with which I was then associated. It proved possible to manufacture all the parts of the mine out of various non-metallic substances except for the pressure trigger, which gave a great deal of trouble. It had to be perfectly reliable under extreme changes of conditions. Finally a curious gadget was worked out called the Bellville spring, shaped about like half an eggshell and made of papreg. At the right pressure the plastic eggshell gave way enough to let the weight that was pressing upon it drop down to the detonator, and that was that!

The moral of this particular enterprise was that you can make just about anything out of wood or wood products, to meet almost any specification that you want. This makes wood invaluable in new or experimental construction. Thus new shapes that are tested in wood-derived materials give specifications that can be transformed to apply to aluminum or other metals that would have been much harder to work into the desired form.

Research in the field of laminated wood construction has been of great value, such as in developing laminated decks for aircraft carriers, and particularly in the creation of glues sufficiently waterproof to make possible the laminating of structural members in ships. Minesweepers, for instance, should be non-magnetic to avoid setting off the mines they are going to sweep; discoveries in lamination are the basis of our present *billion*-dollar wooden minesweeper program.

Laminated skis designed for the ski-troops will be of civilian interest as well, along with laminated shoe lasts, paddles, gunstocks, and an all-wood laminated truck body just developed for the Army.

Research in wood chemistry has had equally spectacular results, also of peacetime value. For instance, the U. S. Forest Products Laboratory has created glues that not only hold together glass or metal structural parts, but then keep their grip at the tremendous temperatures developed in guided missiles.

Again, the Army found that there was danger of a shortage of glycerine, an essential ingredient of some explosives, because as detergents become more widely used and cities increasingly add water-softeners to their water supplies, the production of soap will fall off, and glycerine is principally a by-product of soap manufacture. Methods of making glycerine from wood, both by fermentation and hydrogenation, have therefore been developed to assure a continuing supply under all circumstances.

Better and Cheaper Products

Discoveries in sandwich construction are opening up exciting prospects for peacetime as well as military use. Originally, a balsa core was used, with plywood facings. Britain's famous Mosquito bomber was built on this principle. Later, other forms of sandwich design were applied to hutments, cargo floorings for aircraft, and even guided missiles. The Navy is experimenting with a boat that has sandwich sides consisting of a paper honeycomb core covered with glass fiber! The civilian application of these discoveries will give us better and cheaper prefabricated houses, trailers and other products.

There is also an indirect aspect to the importance of forest products research in national defense. Timber constitutes one of our principal natural resources, one that unlike coal and oil is forever renewable. Wood processing is our fifth greatest industry. The most effective possible utilization of this tremendous national asset, and the manpower working with it, is a requirement of national security, since waste in any such major element of our economy would reduce our overall potential strength.

Research, which gives us new and more efficient techniques as well as new and more useful products, is the answer. Development of any new or better civilian way of using wood affects defense as well, because it may release men or vital materials for other important jobs.

FRANK M. BRANDON, Vice President of

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We know of the admirable work now being done in wood products research by private industry—which I read of with such interest in the *Journal*—and by government agencies, notably the Forest Products Laboratory. I have described some military aspects of this work. Great and stimulating challenges always remain, however; problems whose solution could revolutionize the field. I can think of many: a use for presently wasted lignin; cheap large-scale uses for low-grade hardwoods; improved log utilization practices; integration of forest industries, when this is suitable; and of course the fundamental problem of more efficient forest management. At present we probably do not get one-half the wood crop that theoretically we might, with existing resources, and of a tree that arrives at the mill not a quarter ever reaches the consumer.

The solutions to these problems are admittedly of excessive difficulty. But there are promising indications for the future. For example, during the war we built a plant to make yeast from wood virtually without waste products. And in Sweden, under the pressure of the war, there was extraordinary progress in integrating forest industries so that the waste products of one became the raw materials of the next. Sweden as a result produces marketable goods from almost twice as much of a given quantity of wood as we do! In America, many regions have greatly expanded their wood harvests through intelligent forest management.

Fuller Utilization

Such new products as papreg, compreg, and enrup, new techniques like sandwich and honeycomb construction and radio frequency curing, enable us to use wood better and in jobs not formerly possible. To give another example, the Timber Engineering Company's new method of laminating and bending wood means that where previously only a few trees in an oak forest—the high-quality white oaks—were suitable for bending, red oak as well can now be used, making a much higher proportion of the forest available. Likewise, the Navy's research programs on wood-rotting fungi, marine borers, and tropical woods promise to be of wide value.

It is worth remembering, however, that the wonderful achievements of recent years have been carried out on a research budget of a fraction of one percent of product value, as against an outlay in most industries of at least two percent. I like to think of what might be done on a budget more nearly commensurate with those of other industries if so much has been possible with this relatively small expenditure.

Above all, we must not neglect basic research. It is too easily relegated to a minor place beside the spectacular discoveries of applied work. The applied-research discoveries of today are based on earlier fundamental research, just as a tree has to grow before it can be cut.

I should like to see, for instance, a panel of the next annual meeting of the Forest Products Research Society consider ways and means of encouraging the industry to carry out more extensive basic research. Although most of this type of work will necessarily be carried on by the Forest Products Laboratory of the Department of Agriculture and in the laboratories of our great universities, private industry should take an active part in stimulating and supporting it. Particularly under present world conditions, a vast stockpile of basic forest product knowledge is a defense necessity—as our experiences in World War II proved—beside being at the heart of peacetime progress.

This, of course, is the idea for which the Forest Products Research Society has always stood. And it is with that in mind that I am particularly glad of this chance to salute the Society and its members through the pages of their *Journal*. Their splendid work is as vital to the military strength as it is to the peaceful welfare of our country. May it continue and grow!

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The Perkins Trade Mark is your guarantee of quality and reliability when you purchase glues. Since 1899, customer-confidence in Perkins has grown steadily—a deserved tribute to superior products backed by competent service and rigid ethical standards. When you use a Perkins Glue in your operations, you'll agree with other leading woodworkers—*that Perkins serves you best!*

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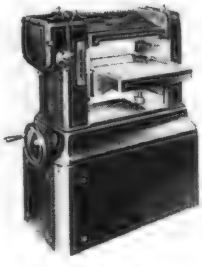

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Forest Products in Review

The following special reports present the first FPRS Annual Review of technical developments and trends in major segments of the forest products industry.

These reports, prepared by FPRS Subject Matter Committees, have a two-fold purpose: To keep our members abreast of significant technical changes taking place in a dynamic forest products economy, and to provide a ready reference of selected bibliographies of the outstanding papers and publications by fields.

FPRS' 13 Subject Matter Committees are one of the most important works of the Society. Open to all members of FPRS, these committees combine the talents of the best-informed individuals as well as those having growing interest in the field. Fields served by the committees are: Chemical Utilization, Education, Finishing, Glues and Gluing, Logging and Milling, Machinery and Machining, Marketing, Packaging, Quality Control, Veneer and Plywood, Wood Drying, Wood Particle Board, and Wood Preservation.

The Veneer and Plywood Industry of the U. S. and Canada[1]

H. O. FLEISCHER

Chairman, FPRS Veneer and Plywood Committee

This first annual report goes back several years to develop the story of the present status of the veneer and plywood industry, its equipment and its processes. Recent trends and developments, and raw material supplies, present and potential, are discussed. The bibliography lists important American reports that have appeared during the past 5 years.

IN THE PAST HALF-CENTURY, the veneer and plywood industry of the United States developed from an infant industry to one consuming almost 2½ billion board feet of logs in 1952. The interruptions that occurred in the upward trend of veneer and plywood production have been minor and of short duration. A picture of the growth of the veneer industry over a period of almost 50 years, in terms of timber consumed (exclusive of lumber for cores and other uses), is given in figure 1. The per capita consumption of timber for the manufacture of veneer in the United States for the same period is given in figure 2.

If present trends continue, it is likely that 1955 will see an annual per capita consumption of timber for veneer of 15 board feet, log scale. Translated into products, the present United States annual per capita production of softwood plywood is about 20 square feet (⅜-inch basis), that of hardwood plywood is about 9 square feet, surface measure, and veneer products account for another 23 square feet of veneer, surface measure.

In Canada, about 280 million board feet of timber were cut into veneer in 1952. Plywood production in Canada amounted to 595 million square feet (¼-inch basis) in 1952, of which 464 million square feet were softwoods and 131 million square feet were hardwoods.

The veneer industry is thought of as requiring only the choicest of timbers, yet it has managed to survive and grow on a resource that is constantly diminishing in volume and quality. This striking phenomenon is a testimonial to the desirable attributes of the product and to the technical competency of the industry.

The term *veneer* refers to thin layers or sheets of wood, produced on a lathe, slicer, or saw. It may be used as a single ply, or as a combination of plies bonded together. *Plywood* is a panel material generally consisting of three, five, or more plies of veneer, or of veneer and lumber bonded together, with the grain of alternate plies arranged at right angles to each other. The resulting product can be made in large sheets and has improved properties with respect to dimensional stability and strength.

The Industry

Softwood veneer and plywood, mainly Douglas-fir, are produced primarily in Washington, Oregon, northern California, and the province of British Columbia. Recently the industry has expanded to Montana, Idaho, and Alaska. In 1953, this industry consisted of 108 plywood plants, 47 veneer plants tributary to plywood plants, and a number of container veneer plants. A modern softwood veneer and plywood operation may represent an investment of approximately 2 million dollars in

[1] The author wishes to thank Mr. John Lutz of the Forest Products Laboratory for assistance in preparing this report. Members of the Veneer and Plywood Committee who assisted in its preparation were Mr. D. G. Miller, Ottawa Laboratory, Department of Northern Affairs and National Resources, Forestry Branch, Ottawa, Canada; Dr. James Bethel, School of Forestry, North Carolina State College, Raleigh, N. C.; and Mr. M. B. Christian, Director of Research, Chicago Mill and Lumber Company, Tallulah, La.

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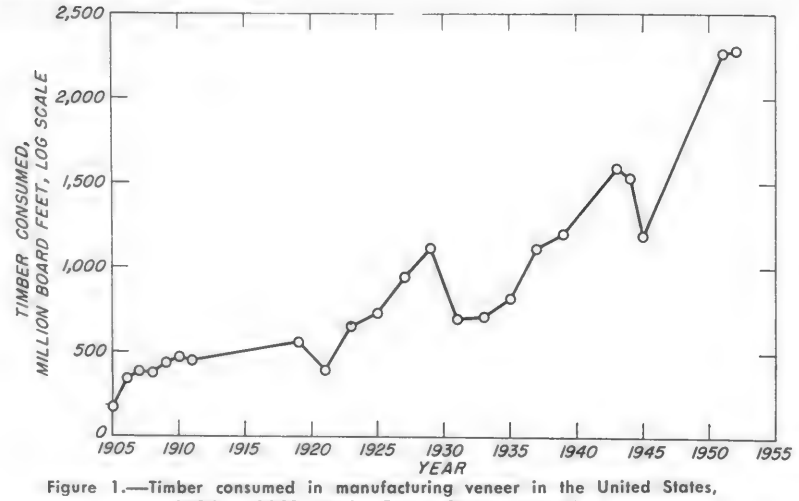

Figure 1.—Timber consumed in manufacturing veneer in the United States, 1905 to 1952 (Basis: Census Bureau reports).

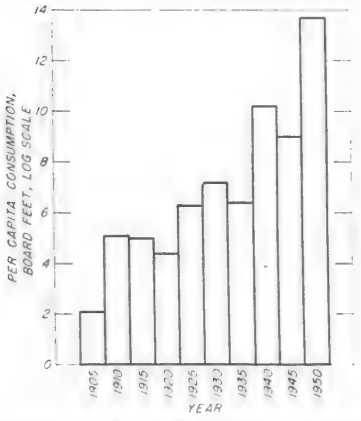

Figure 2.—Per capita consumption of timber for the manufacture of veneer in the United States, 1905 to 1950 (Basis: Census Bureau reports).

plant and equipment. Major items of equipment are rotary lathes, clippers, driers, glue spreaders, presses, sanders, and panel saws. In the softwood industry much accessory equipment has been added in order to get a high degree of mechanization. Green veneer plants represent a recent development in the softwood industry, aimed at reducing the required investment in areas where the log supply does not justify a major establishment. In these plants, the lathe is the main piece of equipment, and the veneer is shipped by truck or rail to the parent or contracting plant where it is dried and processed into plywood. Several western mills slice edge-grain veneer of Douglas-fir, knotty pine, and imported woods for the general market.

The hardwood veneer and plywood industry is scattered throughout the eastern half of the United States and Canada. It is estimated that there are between 600 and 700 mills producing veneer, and about one-quarter of these also produce plywood. Major items of equipment vary with the product but generally are the same as in the softwood industry. Much of the accessory equipment found in the softwood mills is often lacking. The greatest concentration of productive capacity is in the southern and southeastern United States, where sweetgum, water tupelo, and black tupelo are the most important species used. In the Lake and Central States, birch and maple are the most important species. Yellow-poplar is important in the Middle Atlantic States and adjoining regions. In Canada, the hardwood veneer and plywood industry is concentrated in Ontario and Quebec where there are about 35 veneer and plywood plants. Birch and maple are the main species used.

The manufacture of fancy face veneer is a specialty operation in about 50 plants scattered throughout the eastern states, with a large concentration in the Ohio River Valley. Much of this veneer is made by the slicing process from native and imported logs, and practically all of it enters the commercial market. There are three such plants operating in eastern Canada.

To distinguish it from fancy face veneer and from container veneer, the term "commercial veneer" is usually used to identify the great bulk of hardwood veneer going into plywood production. Most of this veneer is rotary cut from native hardwoods. It is dried at the cutting plant and either processed into plywood or sold to plywood mills. Hardwood container veneer is generally cut by the rotary process at plants that do not produce commercial or fancy veneers.

The conversion of logs into veneer and plywood requires the expenditure of considerable manpower. The industry is therefore considered favorably from the standpoint of furnishing employment to the community in which it is located. Many operations around the mill, such as scaling logs, operating the lathe, grading veneer, and gluing require considerable technical skill. Many processes, however, are mechanized so that hard manual labor is largely eliminated. Employment in the veneer and plywood industries of the United States, as of July 1, 1944, was estimated at 51,610 workers in veneer and plywood plants, plus an unspecified number engaged in the logging and transportation of veneer logs and bolts. In 1952, the 50 veneer and plywood plants located in Canada had an average of 7,815 employees.

Types and Uses of Products

Classification of Veneers: Veneers may be classified as face veneers (including fancy and figured), commercial veneers, container veneers, and special veneers. Face veneers are generally cut on a slicer or lathe from carefully selected logs, crotches, burls, stumps, and so on. They are generally relatively thin, 1/28 inch being the most common thickness. This veneer is usually sold by sample. The species involved are generally native or imported hardwoods that are esteemed for their beauty, such as walnut, mahogany, and figured birch or maple.

Commercial veneers are generally from 1/20 inch to 3/16 inch thick and are made almost entirely by the rotary process. Commercial hardwood veneers are usually made to suit the buyer's specification and are graded on the basis of defects, such as knots, wormholes, splits, and discolorations.

Commercial softwood veneer is not sold on the open market but is used directly in the manufacture of Douglas-fir or other structural plywood after being graded into "faces" and "cores" on the basis of smoothness, firmness, and the presence of natural defects. It is generally from 1/10 to 3/16 inch thick.

Container veneers are either hardwoods or softwoods, usually produced by rotary cutting, or they may be produced on special shook slicers. Those used in berry boxes are about 1/24 inch thick, while those used for larger boxes are thicker, up to 5/16 inch or more. Many are immediately converted at the point of manufacture into all sorts of fruit and vegetable containers. Other container veneers are shipped to box factories, particularly those producing wirebound boxes. Existing grading rules are not well defined and are based chiefly on properties such as appearance and printability of surface and absence of defects that may interfere with nailing or may damage the contents.

Special veneers are frequently made to meet specific requirements, such as Douglas-fir and Port-Orford-white-cedar for battery separators; birch, mahogany, yellow-poplar, and Sitka

spruce for aircraft; sap gum and white birch for tongue depressors, candy sticks, etc.; and pine and aspen for matches. Most of these veneers do not enter commerce as such, but are generally fabricated immediately into the finished product.

Classification of Plywood: Plywood panels are classified by type and grade. The type is determined by the quality of the glue bond, and the choice of the proper type should be made with a knowledge of the service conditions under which the material will be used. Examples of plywood types and some of the glues typically used are as follows:

Type	Glue line quality	Typical glues used
Douglas-fir:		
Exterior	Permanent under exterior use	Phenolic resin (unextended)
Interior	Water resistant	Soybean or extended phenolic resin
Hardwood:		
Technical and type 1	Fully waterproof	Phenolic resin (unextended)
Type 2	Water resistant	Casein or urea resin (sometimes moderately extended)
Type 3	No water resistance required	Starch

The quality of the veneer going into a panel determines its grade. The faces and the inner plies in a panel may be of different qualities of veneer. In softwood plywood, face veneers are generally of good quality intended for painting, whereas cores may contain limited open defects such as knotholes, wormholes, and open splits. In hardwood plywood, color, grain pattern, and matching of adjoining pieces are considered in the No. 1 or custom grade face veneer, and the remaining grades are dependent on occurrence and severity of defects. In lumber cores, the quality of the lumber and the maximum width of strips are usually specified, with the object of reducing warping in the finished panel.

Military plywood specifications provide for special products, such as container plywood for domestic and foreign shipment, molded plywood, and aircraft plywood. Aircraft plywood is limited with respect to density, grain direction, and other properties so as to assure a product having the required weight and strength properties.

Softwood plywood production has been built largely around a standard panel size of 4 by 8 feet. Larger panels are produced by scarfing and gluing. Recently smaller panels have been marketed for the "do–it–yourself" user. Hardwood plywood production is rather sharply divided into two types—stock panels, marketed in standard sizes, such as 4 by 8 feet, and dimensioned panels produced to order for specific end uses, such as furniture.

The development of good commercial standards for softwood and hardwood plywood, and the voluntary enforcement of the standards by the producing industry, represents an important step toward maintaining good quality of product. A major segment of the hardwood plywood industry has recently adopted a program of grade marking and certification of standard quality.

Advantages and Uses of Veneer and Plywood: In comparison with other wood products, veneer and plywood are relatively thin. From the standpoint of timber conservation, they offer the opportunity of spreading the available supply of high-quality wood over a large surface area. Based on hardwood veneer-log consumption and veneer production figures in the United States for the year 1953, an average of 10.6 square feet of veneer was produced per board foot of hardwood log consumed. An average of about 2.3 square feet of plywood (all thicknesses) was produced per board foot of logs consumed (exclusive of lumber used for cores). In the softwood plywood industry, average production of 3/8-inch plywood or its equivalent was 2.4 square feet per board foot of log consumed in 1952.

In 1948, about two-thirds of the total softwood plywood production was used for house construction, concrete forms, farm building and repair, and allied uses. The remaining one-third was used in manufacturing industries. The largest manufacturing consumer, using both veneer and plywood, was the container industry. Other major uses were millwork, fixtures, furniture, and prefabricated houses. The trend toward "do–it–yourself" home building has already had an important effect on plywood uses and marketing practice, both in the softwood and hardwood plywood fields.

Softwood plywood has found extensive use for military applications, in shipping containers for domestic and foreign shipment, in building construction at military installations, and many other uses. It is estimated that 20 percent of the Douglas–fir plywood production in 1950 went for military uses.

In 1948, about 263 million board feet of native hardwood veneer were used by the manufacturing industries, excluding containers. This was manufactured into plywood and used largely in the furniture, fixture, millwork, and cabinet industries. The major species used were sweetgum, yellow-poplar, birch, tupelo, maple, and oak. Hardwood plywood serves for many specialized military uses, outstanding among which is aircraft plywood made primarily of birch, yellow-poplar, sweetgum, and mahogany. The use of hardwood plywood for construction in the form of wall paneling and the like is growing rapidly. Figures for 1953 indicate that 43 percent of the hardwood plywood production (exclusive of containers) was used for construction purposes; 37 percent went for furniture, radio, television cabinets, and the like; 18 percent went into other industrial uses; and 2 percent, miscellaneous.

A large volume of both softwood and hardwood veneer and plywood, amounting to about 627 million board feet of logs in 1948, was used in the manufacture of containers. Contrary to popular opinion, wood containers continue to be used in quantities substantially above their prewar consumption, particularly in the export trade.

The major species used for containers in 1948, in order of volume, were sweetgum, tupelo and black gum, Douglas–fir, southern yellow pine, ponderosa pine, maple, yellow-poplar, cottonwood, beech, birch, and elm. Container uses of veneer and plywood may be divided into (1) baskets, hampers, berry boxes, and other veneer packages; (2) wirebound boxes and crates (primarily veneer); and (3) plywood boxes and drums. During the period 1940 to 1948, the basket, hamper, and veneer-package industry annually used about 1 to 1½ billion square feet of veneer. The plywood box and drum industry used from 500 to 750 million square feet of plywood per year, and the wirebound-box industry consumed from 150 to 180 million board feet of veneer annually.

Recent Trends and Developments

Mechanical Improvements: The softwood plywood industry on the West Coast is highly mechanized. New developments spread rapidly through the industry because it is concentrated in a small area and well organized to provide for an exchange of information. Because of the necessity of developing mechanical equipment to handle large logs and large volumes of wood, and the relatively high wages paid, material-handling equipment was developed early in this industry. As a result, in 1944 this industry produced more than half of the country's plywood with 20 percent of the country's veneer- and plywood-plant employees. In more recent years, the emphasis in the fir industry has been on developing and improving equipment to conserve and retrieve materials. In the eastern hardwood industry, a standard pattern

does not apply, particularly among the older mills. Newer mills are highly mechanized, and in general, the trend is entirely in the direction of mechanization.

A recent change that results in the conservation of materials is the scraper-head debarker in place of the cutterhead machine. This breaks the bark off clean at the wood surface, without removing any wood. The importance of this development will continue to grow as smaller and more irregular logs enter the mills.

Core lathes have recently become common in softwood mills. By further cutting the cores dropped from the large lathes to smaller diameters on core lathes, the yields from softwood logs can be increased by from 3 to 10 percent, although the product is generally suitable only for inner plies in plywood.

Recent improvements in lathe design have been minor. The addition of hydraulic chucks has shortened the nonproductive time of the machine. Important changes have been made in the driving mechanism, first by the installation of individual direct-drive steam engines that provide power, speed, and adaptability required for efficient production. More recently, special electronically controlled electric motor drives have come into use. These are adequately powered, versatile drives that for the first time automatically provide for a constant cutting speed at the lathe, regardless of the log diameter. Veneer off-bearing conveyors are synchronized with the lathe. The equipment is said to result in better yields because of the elimination of abrupt speed changes and breakage of veneer.

Veneer slicers, used mostly on hardwood species, have not changed in basic design. Hydraulic dogs for holding the flitch to the flitch table and other minor changes have tended to improve the productivity of the machine. Although large slicers still operate at speeds of less than 50 strokes per minute, there are indications that smaller and faster machines may become more popular in the future. The successful development of more rapid veneer slicers would probably have a marked effect on the veneer industry, for it would make possible the use of lower grade of logs for veneer (for example, logs containings severe defects on one side), it would enable the use of species that are not now used because of defects, such as heart checks or ring shake, and in many cases, it would result in a superior product. Box shooks are often sliced on specialized equipment. Shook slicers can produce veneers of limited size at a speed of 240 strokes per minute.

For handling green veneer, mechanized storage-conveyors or veneer-reeling equipment are becoming common. When veneer is off-borne by hand, it must be torn at frequent intervals and, for convenience, it is often clipped in multiple sheets. These practices are more wasteful and inefficient than mechanical handling methods.

Veneer-drying equipment is constantly being modified and improved. For example, in the past few years gas-fired driers have come into use, and cross-circulating veneer driers have become more popular. One radically different method of handling veneer through a mechanical drier involves feeding it in a continuous band through the drying tunnel and clipping it to size behind the drier. This method results in less clipping waste than the conventional method, but the drying conditions are more difficult to control. In general, however, progress in this field is being hampered by a lack of a basic knowledge about the drying of wood under the conditions used in the veneer industry.

Veneer-patching equipment has become very common in the softwood plywood industry. The better types of patches used to eliminate knots, pitch pockets, and other small defects from face veneers are glued in place in the veneer before assembly into plywood panels. Cheaper "plug" patches may be used on larger defects in face as well as core veneers to bring defective veneer up to certain standard requirements. Ten to twelve patches in a 4- by 8-foot face veneer are not infrequent. In hardwood veneers, patching is less common, possibly because the type and pattern of defect may make it more desirable to eliminate it by clipping than by patching, and partly because patching is more difficult in the thinner veneers that are common in the hardwood industry.

Veneer edge-gluing equipment is now common in the plywood industry. Softwood veneers are regularly glued in order to obtain large faces from narrow clear cuttings that are clipped from defective veneer. In the hardwood industry, fancy face veneers as well as crossbands are frequently edge glued or taped. Electronic edge gluers are used in the hardwood industry to glue strips of core lumber into core panels. Some operators are using these machines, operating continuously at speeds of 15 to 30 feet per minute, to replace the older clamp-carrier, core-gluing units. Recently, electronic machines have also been developed for veneer edge gluing.

Panel patching or "repatching" of plywood is commonly practiced both in softwoods and in hardwoods. Small defects are removed with shallow-cutting saws, routers, or chisels, and are replaced with patches, shims, or plastic compounds. Lumber-patching equipment recently developed may become important in the production of lumber cores from defective hardwood stock.

The plywood sanding operation may remove up to 10 or 15 percent of the best material in a plywood panel. In hardwood plywood, sanding defects may be the cause for reject panels, but with improved cutting and improved sanding equipment, the allowances for sanding could be reduced with a subsequent saving in material.

New and Modified Products: In spite of its many advantages, plywood may develop certain defects, such as face checks, more readily than lumber. This is particularly true of panels exposed to severe weathering conditions. Mechanical modification of the surface by striating it with many small longitudinal grooves has been successful in hiding the surface checks and in obliterating at least in part a pronounced grain pattern that may sometimes be objectionable. Other surface patterns may be created by wire brushing or by stamping or pressing on an artificial pattern. By the latter method, some plain woods have been given the appearance of imported or highly figured woods.

The trend in both the hardwood and the softwood industries is to promote the acceptance of more irregularities and defects in the wood surfaces. In hardwood plywood, small irregularities that would not interfere with finishing and general utility of the panel are being glamorized under the name "natural character marks." In the softwood field, unsanded exterior-type plywood containing limited face defects is grooved at intervals to break up the continuity of the surface and sold under the name "Texture-111." These developments are well worth while, for they result in a greater production of serviceable and attractive material from a given quantity of veneer logs.

Overlays applied to veneer and plywood cause major changes in the surface and in other properties. Overlays may vary all the way from kraft paper to high-density, plastic, decorative tabletop laminates. Overlays are generally applied to both panel surfaces in order to retain a balanced construction, but for some products a one-sided application is desirable.

Simple overlay constructions are made using veneers 1/16 to 3/16 inch thick, with kraft paper bonded to one or both sides. Some of these are intended for container use, some for nonstructural use in furniture, such as drawer bottoms, dust separators, and backs, and some for house construction. Container

panels made from defective veneer and surfaced with kraft paper are already produced in volume and are likely to become increasingly important in the container field. Overcup oak, a lowland species that is difficult to use for conventional products, is used in quantity in the manufacture of one veneer-paper product. Some knotty softwoods are also being considered for such products. Some ingenious processes have been developed, and it appears that this type of product may take on considerable importance as a method of utilizing low-grade veneers and producing an improved light paneling material.

Overlays used on plywood panels generally consist of papers treated with synthetic resins to render them serviceable under adverse conditions, such as high moisture. Paper plastic overlays of moderate density are used to mask defects in plywood surfaces and to provide a good painting base. Sound knots, simply made patches, checks, and coarse grain can be covered. Another process that accomplishes similar results uses a mixture of powdered wood and resin as the surfacing material.

The high-density, paper plastic overlay group use more expensive papers with high resin contents to produce a hard, water- and abrasion-resistant surface. The greatly improved surfaces make the plywood more serviceable for certain severe applications, such as concrete forms. The added expense of the overlay is justified in this case because of the added life of the forms and the smooth concrete surfaces obtained. When used with decorative covers and melamine surface sheets, sometimes with a thin metal interleaf to prevent cigarette burns, panels of this type are made into table tops and other specialized products.

The development of overlaid plywood products is still in its infancy. In the softwood industry alone, production rose from 8-½ million square feet in 1949 to 32 million square feet in 1953. Further research will undoubtedly widen the field of application of overlays, and it is expected that as the industry comes to rely more heavily on second-growth timber and logs of alternate, more defective species, overlays will become essential to the production of a high-quality product.

Quality Control: Effective quality control in the veneer- and plywood-production process can eliminate production difficulties and losses that result from poorly prepared logs, poor cutting, inadequate drying and conditioning, poor gluing techniques, and many other causes. Some of the large mills have adopted statistical quality-control and testing programs. Effective tools for good quality control in the veneer- and plywood-making process are only partially developed, and additional research is needed.

Manufacturers' associations are working toward the maintenance and improvement of quality standards in some portions of the industry. The development of strong manufacturers' associations is an aid to the industry in stimulating research, in bringing about wider dissemination of technical knowledge, in promoting standardization of the product on a high level, and in maintaining demand for products in a highly competitive market and under increasing difficult raw-material-supply conditions.

Developments in Allied Fields: The growth of the plywood industry is intimately related to developments in allied fields. Engineering data have provided the information needed to properly design plywood structures. Developments in glue technology have made it possible to produce plywood that can be used under adverse conditions. Special developments have made possible the use of glues cured by high-frequency heat applications, the edge gluing and patching of veneers, and the assembling of plywood products under a variety of conditions.

The application of fire-retardant chemicals to plywood has facilitated the use of plywood in large structures, such as military installations, hangars, hospitals, etc., where its use would otherwise have been barred. Preservative treatment makes its possible to use exterior plywood under conditions that favor decay.

Raw Material Supply and Limitations

Log Procurement and Shortages: In the softwood industry of the Pacific Northwest, veneer logs are no longer generally obtainable on the open market. In recent years, plywood producers have been forced to line up specific sources of logs, to acquire timberlands, and to trade logs with sawmills and pulp companies. Plywood companies reportedly have acquired sufficient stumpage to meet about half of their current requirements, and must rely on private and public timber tracts for the balance. The logs are still generally produced on large-scale logging operations, using heavy mechanized equipment. Trucking distances are often very great.

Hardwood veneer logs used by eastern veneer and plywood plants are obtained from a variety of sources, including veneer-company operations, farmers, independent loggers, lumber companies, and importers. Log buyers for the larger companies often cover many states. Logs and bolts are cut mainly by small operators using limited mechanized equipment, and are transported to the mills mainly by trucks.

Shortages of high-quality veneer logs exist in every part of the country. On the West Coast, the quality of the logs going into veneer production is decreasing. It is estimated that 15 to 20 percent of the total volume of logs consumed in veneer production in Washington and Oregon in 1950 was No. 2 sawmill logs. This is in an industry that before the war operated largely on No. 1 peeler logs that yielded 50 percent or more of clear face veneer. Several mills have been set up specifically to produce veneer from small second-growth logs or logs of comparable poor quality. In spite of the inadequate current supply of veneer peeler logs, plywood production on the West Coast increased by about 450 million square feet in 1953.

In the eastern hardwood industry, mills are being forced into longer log hauls and many are forced to accept lower grades of logs. Smaller diameters and substitute species are becoming more common. The shortage of birch peeler logs is forcing some Lake States operators to import Canadian birch logs. An obscure disease, "birch die-back," has severely ravaged supplies of birch peeler logs in eastern Canada. Latest indications are that the intensity of the birch die-back attack is decreasing.

Reduction in Manufacturing Losses: In the rotary-cutting process, the outer clear portion of the log is used to excellent advantage, without loss of saw kerf as occurs in sawing. Veneer manufacturing losses occur in the form of end trim, roundings, breakage, cores, and veneer clippings. In Douglas–fir logs, these losses average 30 to 50 percent of the original log volume, yet in value they do not represent an equivalent portion, for the lost material is largely defective. Additional losses through shrinkage in drying veneer, processing, panel sawing, and sanding reduce the recoveries to 35 to 50 percent of the log volume. In hardwood plywood, losses may be somewhat higher, particularly in the veneer slicing process and in the matching of fancy faces.

Losses are being reduced by means of mechanical improvements, yet the quality of the logs going to the industry has also decreased so that no net gains have been attained.

Improvements in utilization practices are not restricted to the mills alone. Woods practices have an important bearing on the recoveries obtainable from peeler logs. Proper log lengths must be cut, with consideration to the defects that may affect veneer yields. One large veneer mill finds it profitable to send technical men into the woods

ahead of the falling crews to mark trees for cutting, indicating the number and lengths of veneer logs to be bucked in each tree.

The proper segregation of logs into veneer, sawmill, and pulp logs presupposes the existence of a sound system of log grading. The veneer industry as a whole is weak in this respect, for in many parts of the industry, no log grading is attempted. In other parts, log grades have been developed empirically, and may have pronounced defects. Research is only starting in the development of technically sound veneer-log grades, based on a study of species characteristics and defects, and the yields obtainable from the logs.

Rapid developments have occurred in recent years in the manufacture of hardboards from veneer and plywood manufacturing waste. In some cases, hardboard panels made from chipped waste and from inferior roundwood are replacing high-quality hardwood lumber usually used in the manufacture of lumber core and other thick plywood.

The Use of Smaller and More Defective Logs: Size is a most important consideration in the choice of good veneer logs. The better grades of commercial veneer, suitable for faces, come from the outer parts of logs; the center portions of logs often yield defective material suitable only for inner plies and representing much waste. Smaller logs therefore result in a reduction of the percentage of face veneer, more waste, and a higher operating cost. On the other hand, relatively small, defect-free logs are sometimes found to yield more face veneer than large, overmature logs of the same species since the latter may often have serious defects that may limit the quantity and quality of the veneer yield. The utilization of very small logs is contingent not only on economic factors but also on the acceptance by the public of smaller panels and of panels with the face grain running in the short dimension, as in Europe. It is possible that the log supply situation will eventually force the adoption of specialized equipment and methods used in some European countries for producing veneer and plywood from small logs.

An important development on the West Coast is the possibility of using Douglas-fir logs containing white pocket, caused by the fungus *Fomes pini*, for veneer. At present, a large volume of timber is being left in the woods in central and southern Oregon because the gross scale is reduced by two-thirds or more as a result of white-pocket attack. Recent studies have shown that many such logs are peelable, and some white-pocket plywood is being produced commercially. If this material meets with acceptance for certain uses, it will represent a potential supply of additional peeler material.

Use of Alternate Species: The largest potential supply of veneer logs in the country is represented by those species not commonly used for this purpose now. Research has demonstrated the suitability of many of these species for veneer, and industry is making efforts to utilize some of them.

In the western states, softwood species that may be expected to become more common in plywood are redwood, the true firs, hemlock, and western larch. Redwood is already being used in three plywood operations, but because of the hard knots and the brittleness of the veneer product, production costs are high. The true firs and western hemlock often contain many small defects that limit the face veneer recovery. These species could probably be used to advantage in conjunction with paper-plastic overlays. They are used for container veneers on a limited scale. Western larch is a promising species, both for rotary cutting and slicing. In sliced form, it presents a pleasing pattern as a face veneer. Ponderosa pine, sugar pine, western redcedar, Port-Orford-white-cedar, and Sitka spruce are used to a limited extent in the industry, but no expansion in production is anticipated.

There are a number of western hardwoods that could be used for rotary-cut and sliced veneer. Tanoak in Oregon and California attains a good size and quality. Logs are often cut and left in the woods after the bark has been removed for tannin extraction. Other potential hardwood species are red alder, laurel, madrone, chinquapin, and the western oaks. Some red alder plywood is now being produced.

In the eastern part of the country there are many little-used species that will undoubtedly become more important in the future. In the Lake States and in Canada, aspen logs are available in quantity. Although small, they yield good quality veneer and are already being used by several mills in Canada and the northern United States. In the Northeast, beech and red maple may need to be used more extensively in veneer mills. In the South and Southeast, the biggest potential supply of hardwood logs is in the swamp species, sweetgum, tupelo, and black gum, and the various oaks and hickories. The industry has learned to produce good veneer and plywood products from the gums, but so far, the swamp oaks and the hickories have not been generally acceptable. Technical data are already available for making this development possible, and no doubt it will come as soon as economic factors are favorable.

Southern yellow pine is being cut into veneer for use in containers. It has not been used extensively for plywood, probably because economic factors have not been favorable to its introduction in the construction market.

Importance of Imported Woods: The most important recent development in this field has been the great increase in imports of hardwood plywood into the United States. Plywood imports prior to World War II reached a peak in 1937 when about 4½ million square feet of plywood were imported. Imports for 1952 were 86 million square feet and for 1953 were 222 million square feet.

Japan, Canada, and Finland are the largest exporters of plywood to the United States, though in 1953, such exports came from 27 different countries. Because of the cheap labor available to Japanese and Finnish plywood producers, these producers have a considerable price advantage over American producers. It was reported[2] in 1953 that ¼-inch lauan 4- by 8-foot plywood panels from Japan were offered in the United States, duty paid, for $89 per M square feet. This is reported to be approximately $10 per M less than the costs (before profit) to a domestic producer for comparable ¼-inch gum plywood. Finnish birch plywood of similar size and thickness has been offered for sale in the United States at $102 per M. This reportedly is $24 per M less than the cost of birch veneer going into the manufacture of 1,000 square feet of domestic ¼-inch birch plywood. Hardwood plywood producers are making strenuous appeals for import regulations that would rectify these price differentials.

Tropical hardwood logs for veneer production enter the United States from West Africa, Tropical America, and the Philippines. Of these three areas, the Philippines are best developed, West Africa is currently being developed, and Tropical America is developed only in scattered areas. Recent developments in logging equipment and techniques, particularly those that enable logging during the rainy season, are likely to improve the availability of tropical hardwood logs for veneer production.

In 1948, tropical hardwood veneer comprised about 2 percent of all the hardwood veneer used in the United States. Most of this material entered this country in log form since there is a 10 percent ad valorum duty on veneer and at that time the ad valorum duty on plywood was 40 percent. The duty on plywood has since been lowered to 20 percent ad valorum. There is no duty on imports in log form. Imported veneer logs have been used mainly for the production of fancy face veneers.

[2] Cost figures are from reports of the Hardwood Plywood Institute.

In 1949, nine woods: avodire, limba, mahogany, paldao, primavera, sapeli, satinwood, tigerwood, and zebrawood, made up 87 percent of all foreign fancy veneers in inventory. In most cases, each of the above common names includes veneer from a number of species.

In the South there has been a trend to bring in tropical woods as substitutes for such species as yellow-poplar and sweetgum. One of these species, cativo, has been coming into this area in quantity and has been used successfully for cores and crossbands in furniture panels. Philippine hardwoods, particularly the lauans, have been imported in quantity for several years, are used for plywood for door and panel stock.

In 1948, the end uses of all tropical hardwood veneer used in this country were as follows: furniture, 54 percent; radios, 14 percent; professional and scientific instruments, 9 percent; millwork, 7 percent; fixtures, 6 percent; and miscellaneous, 10 percent.

Current research is broadening the factual information about tropical woods and pointing out species that show possibilities for veneer and plywood production. The immediate future imports of tropical hardwoods will probably continue to be mainly for high-grade or fancy veneers. However, there is also a definite interest in importing such utility-grade veneer woods as cativo, gaboon, hura, banak, and orey. Tropical hardwoods will probably offer little competition to softwood plywood, although they may complement it by supplying face material. Tropical hardwood logs may eventually supply an appreciable amount of the higher quality hardwood veneer, but they are not likely to make up a very large percentage of this material in the immediate future.

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Status of Wood Seasoning, 1953-54[1]

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A representative group of seasoning authorities were asked to answer questions pertaining to: 1) air drying, 2) kiln drying, 3) special-drying processes, 4) storage and handling, and 5) general problems related to the seasoning of wood. The assembled report indicates the significance of the advances made in the seasoning of wood and that improved performance is being sought in all phases of wood drying and moisture control.

Air Drying

THE YARDING OF LUMBER or other rough-sawn wood products for air drying has always required considerable labor. To reduce these labor costs, both lumber-producing and wood-using industries have largely converted their yards to "package handling." The conversion is nationwide, and only the small sawmill operator or the small woodworking factory now uses piling methods for air drying that require the handling of individual boards. Where lumber can be self-stuck without loss due to stain and decay, this method of piling is still being used. But even in the arid and semiarid regions of the country, most lumbermen have converted the yards and are now using carriers and lift trucks for package handling and yarding for air drying.

Yarding costs have been reduced by this conversion, although it is difficult to find operations that have good data to actually show the cost reductions gained. One reporter indicated an estimated savings of as much as 40 percent over the hand-built method of piling for air drying. At many lumber-producing and woodworking plants, the savings are obvious, but the conversion of the air-drying yard requiring improved roadways for lift-truck operation, plus the investment in lift trucks, does not seem to be warranted at some of the smaller operations. Labor savings alone merit conversion, although improved piling practices to reduce seasoning degrade of the hand-built, sloped piles can effect considerable savings. One reporter states, "A selling factor in favor of package handling for the use of the fork-lift truck is that management is able to directly account for the savings and give credit to the system providing it. In contrast, good seasoning practices could give the same healthy savings, but there are more chances for this saving to be concealed in other systems of other departments so that the actual saving never appears as large as the estimated saving."

Although conversion to package handling often resulted in an increase in footage losses due to mechanical damage and seasoning degrade, such as surface and end checks, splits, stain, decay, and warp, the losses are being reduced by directed efforts to improve package build-up, yard layouts, roadways, and package placement. The increasing use of raintight covers or pile roofs is one way that footage losses, particularly of the higher grades of lumber, are being effectively and economically reduced. A reporter states, "Drying in package units requires bolsters between packages, and many mills have not given enough consideration to the alinement of bolsters with stickers. Also, some have not been careful enough in sticker alinement, with the result that more warpage may be occurring in package lumber than was formerly found. Other problems include improper foundations, poor roadways, and less roofing than found on 'old style' piles. These are compensated for by faster drying and much less labor. As the yards gain experience in package handling, they improve these faults."

Obviously, where both air-drying and kiln-drying methods are combined at a plant, package handling has many advantages. Perhaps the most important one is the elimination of the need for repiling for kiln drying after air drying. This advantage seems to be stimulating the need for better segregation of lumber for drying items, grades, lengths, and thickness, so that better packages for subsequent yarding and kiln drying can be made. Comparatively small producing mills are installing lumber sorters so that package-making costs can be reduced, as well as to make up units with square ends and well-alined stickers. Along with the increased use of sorters, we find that mechanical equipment for package making is being more widely used. Stackers of various sizes are being developed and installed to facilitate the package-makeup operation.

"Redwood, with few exceptions, is handled in unit packages. Package sizes are not standard, varying from 3 feet to 6 feet in width, and 25 inches to 48 inches in height. The one remaining plant that builds self-stuck units by hand for air seasoning is planning to convert this entire yard to unit packages as soon as possible."

Air-drying studies in the redwood region where packaged yarding is so prevalent have been outstanding in that the factors which influence drying costs have been evaluated. Increased acreage with its additional investment in improved roadways has proven beneficial, for the wider pile spacing has increased the drying rate so that the period on the yard was sufficiently reduced to effectively lessen the total drying cost.

Air-drying practices in the redwood region will continue to improve because certain types of lumber must be segregated for air drying prior to kiln drying, as kiln drying green from the saw is expensive due to the long kiln time and increased seasoning degrade. Redwood lumber is usually segregated into heavy, medium, and light classes, according to its moisture content and ease of drying. Light stock is often kiln dried green from the saw, but medium and heavy classes are first air dried so as to minimize seasoning de-

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[1] This report of the FPRS Wood Drying Committee is based on regional reports prepared by Committee members and others invited to participate. The reporters and the regions they represented are as follows:

*H. Rhodes, New England
*H. Gatslick, New York State
*P. Lane, West Virginia, Virginia, and Eastern Tennessee
W. Smith and *Pat Williams, Jr., South East
W. T. Nearn, Pennsylvania State
J. B. Welch, Ohio Valley
*Fred Dickinson, Michigan State
G. Ostermeier, Upper Michigan, Minnesota, and Northern Wisconsin
R. Brinkmeyer, Illinois and Iowa
*H. J. M. Jorgensen III, Western Tennessee, Arkansas, and Northern Mississippi
M. Lehrbas, Southern States
R. W. Reed, Colorado State
E. S. Kotok, Arizona and New Mexico
*L. Espenas, Pacific Northwest
*H. Smith and *V. Clausen, California
*F. W. Guernsey, Western Canada
*R. S. Millett, Eastern Canada
*Members of the Wood Drying Committee.

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grade and overall drying costs. Very few of the redwood mills still dry light and heavy stock together in the dry kilns.

One mill in the redwood area is now using a predrier, which is essentially a large, low-cost kiln installation operated at temperatures only slightly above outdoor temperatures. The low-temperature predrier is provided with fan equipment to stimulate faster drying due to increased circulation of air than can be obtained in normal piling for air drying. The low-temperature predrier is used in Australia where air-drying conditions are not favorable. Shed drying of yellow-poplar and sap gum under forced-air circulation without the addition of heat has been reported as being quite successful. These woods were dried to an air-dried condition in 10 days, which emphasizes the value of forced-air circulation to accelerate the drying of green lumber.

Not all regions of the country report improved air-drying results. One area, where 80 percent of the region's lumber product is produced by small circular mills, reports poor drying when it is done at the sawmill site. "Self stickering, poor sticker alinement, inadequate foundations, and poor roofs are common practices. Degrade from stain and warp are prevalent. Little or no improvement has been noted at these mills. These mills generally move lumber in the green condition to processing plants or concentration yards for seasoning. Air-drying practices at these yards are generally satisfactory. There is a slow but encouraging trend toward package handling, better piling, and mechanical stain control."

Stain Control During Air Drying: Although blue-stain control in softwoods and hardwoods can be effectively used by the producing industry, sticker stain or sticker marking in certain softwoods and in many hardwoods seems to be of increasing concern.

The redwood reporter says, "The problem of sticker stain is increasing. There are probably two reasons for this increase. First, more and more redwood is going into natural finished siding and paneling on which sticker marks can be very obvious. Second, in surfacing lumber today, the planing mills are taking off a very thin cut. In the past, they often took off enough material to remove the concentrated water solubles that produced the sticker stain on the outer surface of the boards. One mill is studying the problem of sticker stain intensively in their experimental kiln. Several other mills are actively working on methods of reducing the stain by improved yard practices and kiln schedules."

On hardwoods, a reporter states, "Sticker marking in maple, beech, and birch is a big problem. The reason for this is that the northern hardwoods are being used for lighter colored finished furniture and the sticker stain stands out very prominently." Various methods are being tried to reduce sticker marking in air drying both northern and southern hardwoods. Oak flooring manufacturers are now faced with this problem, yet oak has not been a serious problem previously. This is apparently a chemical stain and not a fungus stain. One solution seems to be associated with the use of dry, narrow, special stickers. Special grooved stickers are being successfully used at a northern hardwood operation for kiln drying green maple. If the storage period on kiln trucks is too long under certain weather conditions, sticker marking may result, even though dry, narrow stacking stickers are used. This situation was the reason for grooved stickers.

End Coatings: The use of end coatings to minimize footage losses due to end checking and splitting is generally increased. "End coatings are being used extensively for squares and heavy hardwood stock. Wax emulsions are receiving increased acceptance, but hot wax, tar, and asphaltum mixtures, and proprietary end seals are more generally employed." On end coatings, the redwood reporter writes, "There is a great deal of interest developing on the use of end coatings for reducing end checking in air seasoning of redwood. Figures for several mills in the warmer parts of the redwood region indicated that trim due to end checking may amount to as much as 10 percent of the lumber, while several mills practice spraying all of their lumber going out of the yard, many of the others are experimenting with various proprietary end sealers and other methods of protecting the ends of the packages, such as by the use of end boards or so-called crates and by stickers protruding from the ends of the lumber and by the use of canvas curtains."

Canadian experiments demonstrate that "projecting the edges of the front row of stickers an inch over the ends of the boards reduces end checking considerably. This is especially noticeable when the piles face south, since the crossers shade the ends at the middle of the day when the sun is the highest and hottest." This indicates that end checking can be reduced by careful sticker placement at the ends of the packages. Well trimmed to length stock is needed. Where boards are not trimmed to length, the Canadian "tests have shown less end checking to occur in the ends of the boards which overhang the crossers by 12 inches than in those which overhang by 6 inches, since shrinkage is permitted to occur over a longer length and stresses set up are not so concentrated." End coatings and proper sticker placement at the ends of the loads seem to be a logical way of controlling end checks and splits in the air drying of lumber Footage losses due to these end splits can be excessive, and it can be safely predicted that end coatings will be more often used on our more valuable species and grades.

Summary of Air Drying: Air drying lumber, dimension stock, railway ties, posts, poles, timbers, and the many other mill products, is a low-cost seasoning method. Handling costs, with rising labor costs, increased yarding expenses to the point where mechanical-handling methods became profitable at many mills and factories. The conversion to the package-handling system has introduced many new problems as related to air drying, but these are gradually being successfully resolved. Right now, we are in the midst of this problem of adjusting the methods of package make-up, handling, placement on the piles, and takedown to reduce yarding costs with a minimum of footage losses due to mechanical damage, stain, decay, and warp. Industrial experience, specific research, and extension of information with these problems will materially benefit the industry.

Kiln Drying

Recent developments in lumber drying have been associated with improvements in kiln designs, kiln operation, and kiln-drying schedules. In many instances, these improvements have increased kiln output at lower costs and with less seasoning degrade.

Package Handling: One of the major influences on kiln design has been the increased use of lift trucks for package handling of lumber. At many new installations, particularly where air drying is combined with kiln drying, kiln-truck loads are built up with lift-truck packages. Small plants, using carrier and lift-truck handling equipment, are installing package-loaded, trackless dry kilns, and, in many instances, special designs are developed to fit the particular needs of the plant. As these kilns are loaded from the side, they must have very large doors. New door designs have been developed to reduce weight and heat losses.

Forced-air-circulation, ventilated dry kilns continue to be the most popular type of dry kilns. New installations are generally of the internal-fan type, although some types of external-blower kilns are being constructed. Few new natural-circulation dry kilns have been installed in recent years. Many are in use, however, and they are often converted to a modern forced-air-circulation type, should the structure warrant continued use. New installations of

forced-air-circulation kilns of the internal-fan type are characterized by larger plenum chambers to produce more uniform velocities at high rates of circulation across the kiln-truck loads. These loads are generally flat-piled with the lumber in each course placed edge-to-edge. New and remodeled lumber dry kilns are almost always equipped with control instrumentation of the recording type which automatically controls the dry and wet temperatures and position of the dampers on the vents and fresh-air intakes.

Training Kiln Technicians: The reporters were asked if improved dry-kiln performance has been obtained by kiln-operator training. The activities in this field by the forestry schools, Oregon Forest Products Laboratory, the dry-kiln clubs, the Canadian Forest Products Laboratory, and the Forest Products Laboratory at Madison have definitely been beneficial to the industry. John Devine of the Moore Dry Kiln Company has also conducted many short courses in the kiln drying of lumber, effectively training men to do a better kiln operating job. The short course in kiln drying at the State University of New York, Forestry Department, Syracuse, N. Y., has provided basic information in kiln drying to technicians for many years. Recently, they report, "Almost to a man those attending our short courses in the past two years report far better performance after attending the course." The Canadian Laboratories at Vancouver, B. C:, and Ottawa have 1-week courses in kiln drying each year for representatives from Canadian plants, and they report that the training is effective. The Forest Products Laboratory, in addition to their own 2-week demonstration in kiln drying, assist the Oregon Forest Products Laboratory and North Carolina State College with their short courses in kiln drying, and cooperatively the benefits to the industry have been good.

Dry-Kiln Clubs: The dry-kiln clubs and associations are also effective in improving dry-kiln performance. The objective of these organizations is: "To seek proficiency in this important phase (kiln drying) of the wood-using industry." The active kiln clubs and associations meet at least twice a year. Some groups meet more often. The programs usually include a discussion of one or more technical phases of wood seasoning, usually kiln drying. Plant visits are often scheduled so that club members and guests can see "how the other fellow is doing it." Panel sessions are becoming more popular. Experienced technicians and wood technologists are present to answer questions put to them by those attending the meeting. These kiln clubs and associations are doing a fine job of disseminating the available information on the air drying and kiln drying of wood. Two new groups are being formed in the Midwest. The New England Kiln Drying Association sponsors a 6-day kiln-drying clinic each fall, and the Forest Products Laboratory cooperates by helping with the instruction. The kiln clubs of the West hold joint meetings each spring and the program is definitely adult education in kiln drying.

Energy Demands in Kiln Drying: With increasing fuel costs or shortages of mill or factory wood waste due to greater utilization, the wastefulness of the ventilated kiln becomes more important. The cost of power to produce circulation as related to kiln design is also being given attention by the kiln designer and buyer. Although heat and vapor losses through walls and roofs can be minimized with insulation and vapor barriers and much tighter doors, the energy losses due to required ventilation remain appreciable. Where ventilation is not under good control, the heat wastage, particularly in forced-air-circulation dry kilns, can be considerably greater than that required to evaporate the water in the wood. Kiln designers are again giving attention to ways and means of conserving the heat lost by ventilation, but the greatest immediate accomplishment can be made through better vent control in existing equipment. In areas where fuel is ample, heat losses are of little concern, but where coal must be purchased to keep up steam pressure, the need for better kiln maintenance to reduce heat losses and the use of modern kiln schedules to reduce kiln time are obviously essential.

Furnace-Type Dry Kilns: Although the steam-heated lumber dry kiln is as popular as ever, the economies of the direct-heated, furnace-type kiln, using natural gas or oil for fuel, have resulted in an increasing number of installations of this type of dry kiln. Some designers of this type of kiln installation have developed a prefabricated unit that can be erected at the building site with a minimum of trouble and effort. These prefabricated kilns have insulated metal panels for walls and roof sections. The increased insulation and tightness of construction to keep heat losses to a minimum are advantages that apply to both furnace-type as well as steam-heated dry kilns.

Part-Time Heating: Where kiln capacity is adequate to increase kiln time without holding up production in the factory, part-time heating is often used. The main idea is that the kiln is heated only when fuel is being produced. A typical situation reported, "Part-time drying is a general practice in this area, with shut-downs common at the end of the working day and on weekends. Some operate fans after the steam is shut off to take advantage of heat in the kiln. Insufficient attention is paid to air-drying as a requirement for part-time kiln drying."

Part-time kiln drying should only be applied to stocks where lack of good control of the drying conditions will not cause or increase losses due to seasoning degrade. Thus well air-dried lumber can be subjected to controlled drying conditions for 8 hours and non-controlled drying conditions for 16 hours a day without increasing seasoning losses. On the other hand, control of drying conditions is essential in the early stages of kiln drying refractory green hardwoods, and part-time drying here may cause a significant increase in seasoning degrade.

Another reporter states, "More progressive furniture plants have gotten away from part-time drying and say that they get better results with full-time drying." The increase in kiln time when part-time drying methods are used will vary considerably depending upon a number of factors. One reporter states, "Part-time drying is not practiced except where the kilns are not needed all of the time. Excellent drying and reasonably fast drying can be obtained with our internal-fan kiln on intermittent operation."

Fuel saving is the main objective of part-time drying. In addition, most operators save power costs by shutting down the fan motors when the supply of heat is turned off. The increased kiln time is seldom given much consideration from a cost standpoint as otherwise the equipment would be idle. The increase in kiln time has not been studied in the United States or reported. The Australians report a ratio of 4 to 7 for full-time versus part-time heating (fans on all the time). One kiln operator in Michigan reports that his kiln time on part-time drying is the same as full-time drying. He accomplishes this by heating the lumber to much higher dry-bulb temperatures during daytime heating than he would if he were heating continuously.

In the softwood-producing areas of the South and West, part-time drying is seldom used. The kilns are usually operated on a full-time basis.

Kiln-Drying Schedules: In dry-kiln operation, the drying conditions are changed as the stock drys. The drier the lumber, the more severe are the conditions of temperature and relative humidity. The objective in making these schedule changes is to reduce kiln time. The problem always facing the operator is: When can changes in drying conditions be made to accelerate drying without causing damage? From a purely physical standpoint, the energy

required to (1) heat the wood and water, (2) evaporate the water, (3) overcome hygroscopic forces, and (4) the heat needed to replace that lost by ventilation and heating of fresh air cannot be changed. The total energy assessed against any one kiln charge, however, is dependent upon radiation losses and excess ventilation. Thus, kiln time becomes very important where total energy demands are an important factor in the total costs of kiln drying. Drying schedules greatly influence kiln time, and good kiln technicians are constantly modifying them to gain the advantages of shorter drying time without increasing seasoning losses or reducing the moisture quality of the dried product.

In the East, "much emphasis is being placed upon reduction of kiln time, and Forest Products Laboratory schedules are followed and original schedules modified." Perhaps the influence of a dry-kiln club is indicated, for in another area where a club is not formed, Forest Products Laboratory schedules are being used by a large number of operators, but schedule modification has been attempted by only a few.

Aid to Modifications

The increasing use of Forest Products Laboratory schedules on hardwoods is encouraging, for these schedules are now based on a pattern designed to facilitate modification. Technicians are advised that the Forest Products Laboratory schedules are a basis for kiln operation, but that modifications can be made to reduce kiln time if attention is paid to the factors that cause seasoning degrade. One reporter points out that schedules for hardwoods are being modified by the technicians in the area but usually by trial and error rather than by adjusting according to Forest Products Laboratory schedules. Trial and error can often be costly unless the experimentation is based on a reasonably sound theory. In another hardwood region "the more progressive operators are constantly trying to shorten drying time. Practically everyone using the latest Forest Products Laboratory schedules has boosted them past what is recommended." The writers of the Forest Products Laboratory schedule recommendations wanted just this sort of thing to happen! In the lower Mississippi Valley hardwood area, "no marked changes in kiln schedules have taken place since World War II as far as commercial kilns are concerned. Many studies have been made with regard to kiln schedules for lumber green from the saw. The facts of kiln drying in the Mid-South are that most commercial drying is done on material of 20 percent moisture content or lower. Schedules are usually at their maximum in this range. Therefore, practically speaking, lumber is being dried commercially as fast as present information shows is safe."

In the softwood regions. "Kiln schedules mean time schedules, and they are modifed when time requires such modification in order to increase drying capacity." In the Pacific Northwest, "Schedules in general are fast, and the kilns are geared to operations on the basis of fast schedules. Thus, while drying time is a primary concern, at the present time there is no general concerted effort for the further reductions of drying time. Troubles develop, however, when slower drying stocks make the kiln a bottleneck." Another reporter states, "If the kiln operator is doing his job, he is always making a concerted effort toward the reduction of drying time." In the redwood area, "There is a constant effort among operators to reduce the drying time required for both redwood and fir. One operator, who has an experimental kiln at his disposal, has very materially reduced the time required to dry fir lumber." In western Canada, "Kiln schedules are under constant review by those operators who take their jobs seriously."

As most kilns in operation are of the ventilated type, kiln time is important because of the cumulative effect of excess ventilation on increased energy requirements. Although present kiln installations may not always warrant installation of additional insulation, to reduce heat losses per 1,000 board feet kiln dried, reduced kiln time will effectively accomplish part of the desired energy savings when necessary. Thus, kiln schedules, whether for hardwoods or softwoods, for boards or bowling-pin blanks, are a most important phase of efficient dry-kiln operation. It is encouraging that the regional reporters indicate a nationwide interest in schedule improvement. The many discussions on drying schedules at the active dry-kiln-club meetings are obviously effective in this direction. It is important that they should be, for, given good modern equipment instrumented to give automatic control of drying conditions, and good maintenance, the performance of the unit depends upon the awareness of the technician that schedules and their modification to fit the needs of the stock being dried are the key to efficiency.

Seasoning Degrade in Kiln Drying: The reporters were asked if losses due to seasoning degrade had been generally reduced. A typical report is, "Seasoning degrade losses have been generally reduced by improved kiln-drying practices." Another eastern reporter writes, "Losses due to kiln degrade have been generally reduced. Some plants haven't made any attempt to change their ways and will not train operators or send them to a short course."

Data on losses due to surface checking, end checking, end splitting, honeycomb, and warp have always been difficult to obtain. In the first place, few plants investigate the causes of poor utilization unless exceptional situations develop. The reports, however, show that in the hardwood field a definite improvement has been noted. Increased hardwood lumber prices no doubt have been effective in requiring that the kiln technician control these defects as much as he possibly can. Kiln drying softwoods, on the other hand, is generally at such a high plane of degrade control that the problem is one of maintenance of the quality aspects gained. The redwood reporter states, "It is difficult to estimate the amount, if any, which losses due to seasoning degrade have been reduced. However, most of the redwood mills are acutely aware of seasoning degrade and constantly strive to reduce it." This, we believe, is the real situation in all softwood operations.

The control of surface checking, end checking, end splitting, honeycomb, knot shattering, knot drop out, etc. is generally well known. Careless piling methods introduce the problem of warp control, and, particularly in hardwoods, this defect, if such it is, requires attention. The part that drying conditions play in warp control has not been adequately investigated, and until these basic factors are known, we must continue to recommend piling procedures that are conducive to "restraint to warp."

Equalizing and Conditioning: The objective of the equalizing and conditioning treatments at the end of a kiln run is to produce uniformly dried, stress-free stock at the desired average moisture content. Kiln drying of hardwoods for furniture has demonstrated the value of good moisture control and stress-free stock, and, as one reporter stated, "equalizing and conditioning is a *must* in most kiln operations." Another reporter from a hardwood-using area states, "Equalizing and conditioning is done to a limited extent. Too many kilns are pushed because of production demands. In general, equalizing and conditioning for general overall control of moisture content has a good way to go in most plants." In other areas, conditioning is carried out only when the kiln-dried lumber is to be resawn, which generally applies to the softwoods. "More people every year see the need for conditioning, but equalizing is not widely practiced." One of the western reporters states, "Possibly because there is more reman-

ufacturing developing in the area, as well as a shifting to a buyers' market, here is an increasing interest in drying quality which has resulted in the more general use of conditioning treatments." In the western ponderosa pine areas, conditioning is generally made a part of the kiln-drying process "especially for shop grades where remanufacture is indicated."

Moisture quality implies uniformity of moisture within and between boards. In the wood-using industries this sort of moisture quality is becoming increasingly important, and statistical-quality-control methods are gradually being used to express these moisture standards and determine compliance. The average moisture content best suited for manufacturing, warehousing, and "in-use" conditions are reasonably well known and confirmed by many years of experience. Lately, however, there is evidence that specifications for the average moisture content may require modification to adjust for the change in exposure conditions of wood products in our air-conditioned homes and offices. Statistical-quality-control methods have supplied a way of expressing the degree of uniformity of dryness of lumber or other wood products as associated with the average. Variability statistics such as the "standard deviation" or the "range" will become more widely used as the value of these terms in expressing moisture quality becomes better known. With standards for the average and standard deviation established as guides or measures of kiln performance, equalizing treatments near the end of the kiln run will be more generally used.

Conditioning lumber or other products before the kiln run is completed usually means treating the wood at a higher temperature and relative humidity so as to create a moisture-regain gradient. The heating effect speeds casehardening or "set" relief and the regain gradient produces the increased compression forces near the surface to create the strains that cause the relief of "tension set" to take place. The regain gradient in addition to being influentical in relieving "set" also tends to flatten out the moisture gradient so that a more uniform moisture distribution within boards is produced. Conditioning of hardwoods is considered as necessarily being a controlled equilibrium moisture content treatment so that "reverse casehardening" is prevented. Southern kiln technicians sometimes "steam" hardwoods before pulling the kiln charge. Reverse casehardening may not be serious and the inadequate depth of relief not important for the products made. Many also condition hardwoods by leaving the stocks on sticks in the cooling shed for some time. Softwoods are often "steamed" or subjected to a higher relative-humidity treatment of often quite short duration. Some reverse casehardening may develop, but seldom does it cause trouble.

Equalization and conditioning of kiln charges introduces moisture content and stress-free quality to kiln-dried stocks and is becoming more and more a part of the kiln technician's "bag of tricks" to produce properly dried lumber and wood products for a great variety of fabrication needs.

High-Temperature Drying: The publicity given the German high-temperature dry kilns prompted asking the reporters if anyone were using kiln temperatures in excess of 220° F. The Ottawa, Canada, reporter pointed out that three high-temperature kilns of German design are located in eastern Canada and one in western Canada. It was not known if the unit in western Canada was in operation. It is interesting to note that one reporter called attention to the fact that perhaps many of the older natural-circulation kilns may have been operated at times at temperatures exceeding 220° F. The successful performance of these older natural-draft kilns was probably related to the operational limits of kiln drying only well air-dried woods in them. In the United States and Canada, the adoption of drying temperatures in excess of 220° F. is still in the experimental stage. One reporter writes, "One outfit has tried high-temperature drying and reports success with 4/4 maple on two consecutive runs. The temperature was above 220° F., but just how high they don't know. They maintained a wet-bulb above 160° F. throughout the run in effort to effect maximum heat plasticizing, and dried the maple from 85 percent to 8 percent in 4 days. No attempt to equalize or condition was made, and slight reverse casehardening was reported." The Dryalator, made by an American firm, probably comes close to the design and operation of the German high-temperature kilns. The commercial status of the Dryalator, however, is not known. One installation is being used to kiln dry green eastern white pine 4/4 lumber.

The interest in accelerating drying by the use of dry-bulb temperatures in excess of 220° F. has warranted further research. The German kilns are designed to provide high rates of circulation in tight and well insulated kilns. The objective is to reduce the radiation and excess ventilation heat losses per kiln charge as much as possible, and thereby reduce energy demands per unit dried. The basic problem is whether our commercial species, in the sizes that are being dried for our various products, can be subjected to these high dry-bulb-temperature drying conditions without damage. The Ottawa, Canada, Laboratory is continuing with their investigations of the high- temperature drying effects on Canadian woods. The Vancouver, B. C., Laboratory is also installing kiln equipment to conduct high-temperature-drying studies. In the United States, the Forestry Department of North Carolina State College, Raleigh, N. C., is planning to install equipment to make similar studies. For small woodworking plants, the German design of a small self-contained, prefabricated kiln unit with a minimum of controls has considerable appeal. Even so, drying quality and drying costs must be quite evident before such kiln units are accepted by the American industry. Studies by the Canadian Laboratories and others on high-temperature drying, and the performance of special drying equipment for such treatment, will be watched with considerable interest.

Dry Kiln Structures and Maintenance: The conventional, ventilated, lumber dry kiln is subjected to changing conditions of temperature and relative humidity that cause deterioration of the structure and corrosion of metal equipment, such as heating coils, baffles, fan blades, etc. One reporter states, "Commercial kiln constructions stand up fairly well, but many home-built kilns have reported deterioration. Steam coils seem to be the chief offenders. Protective coating of metal interiors is used to prevent corrosion and good results have been reported in a few instances with aluminum paint. Cleaning of steam coils at regular periods was also reported to produce best maintenance corrosion prevention."

Another reporter suggests that masonry walls and asbestos roofs are best materials for kilns. But this will be debated by kiln designers who are becoming more interested in prefabricated units using corrosion-resistant aluminum. The structure of the masonry kiln deteriorates due to thermal expansion and contraction, and deterioration is probably further accelerated by moisture changes. A good moisture-vapor barrier applied to the inside of these kiln walls is essential to keep out as much of the moisture as possible. Lumber dry kilns built of wood, with outside coatings to "pretty up the building," trap moisture in the wall and rot quickly develops.

Another reporter writes, "Practically all of the kiln buildings that were designed by any of the reputable kiln companies are giving good service if properly maintained. In the newer types of construction, the 12-inch, cin-

der-block wall seems to be the most susceptible to deterioration and requires the most maintenance to keep the moisture out of the wall. In isolated cases, corrosion of metal parts is a problem. We feel that the way to solve it is to eliminate as much as possible materials which will corrode. All our sheet metal work now is fabricated from aluminized steel, which will not corrode and requires no painting. Our ceiling baffles are pure aluminum, which makes them light and corrosion proof. The only satisfactory maintenance that I know of is to paint the metal parts with any of the commercial kiln paints."

A kiln designer writes, "Because of building costs, kiln structures are not as well made as they should be for the modern schedules that use high temperatures. It is very difficult to keep masonry walls dry, and, if they are not kept dry, they will lose heat and in time deteriorate. The same applies to the roof using Perlite and Zonolite materials which, of course, are moisture absorbent. If the moisture barriers are not put in properly to stand the temperatures and humidities and keep up their service, then such types of roofs using transite, Zonolite or Perlite in time will deteriorate and fall in. Corrosion, of course, is a factor, but if the walls and roof are properly insulated and painted with special paint, corrosion is not any serious consequence."

To the kiln technician, kiln maintenance is a constant worry. One of them points out, "A reverse-circulating kiln is very hard on the inside of a brick or concrete chimney. Asbestos tile is very satisfactory. Dry kiln paints are satisfactory for most metal parts. One exception is the track rails just inside the door. Corrosion has been very rapid in this area since converting to the cross-circulation, fan-type kiln. This trouble has been remedied to some extent by cutting the rail under the door and leaving a 1/4-inch space. Corrosion also attacks the electrical conduit that enters the kiln in this area. Our conduit is grouped at the floor level. This trouble was eliminated by building a form to include this area around the conduit. This form was filled with asbestos roofing cement to cover the conduit."

Maintenance seems to be the key to good service life from lumber dry kilns. An owner writes, "Structures with proper care are giving very satisfactory operation. We overcome the corrosion of metal parts by periodic treating with corrosion-resisting paint." A western reporter writes, "Masonry buildings in this area stand up well, but wooden buildings are short lived because of the higher temperatures and relative humidities commonly used in this area. However, some laminated wood roofs have given good service. Corrosion is generally not a serious problem so far as most of the kiln equipment is concerned, but some plants do have problems in corrosion of steam pipe, possibly due to local peculiarities of the water supply." Corrosion from the inside of the steam-heating coils calls for treatment of boiler feed water. Another western reporter states, "We have found that wooden kilns have a life of about 10 to 15 years, provided temperatures do not go higher than 170° F. Corrosion of metal parts is a definite problem in drying western hemlock."

Piling of Lumber for Kiln Drying: The piling of lumber for kiln drying is improving. Warp control is related to piling, and the footage losses due to improper stacking become quickly apparent. The trend is indicated by this report: "Lumber piling for kiln drying is generally improving, and stackers aid in better sticker arrangement and box piles." The objective of piling is to separate the layers of lumber so that heated air can be carried to the board faces. Although some kilns are still in operation that require "vertical" stacking, all modern kiln installations require flat piling of the lumber. The use of poor stickers, misalinement of stickers, too few stickers per layer, and the piling together of random lengths to produce ragged pile ends results in distortions often requiring trimming or ripping. Increased lumber values warrant improved piling methods to reduce these losses. Stacking devices to produce well-piled lumber replace the need for experienced stackers. As one reporter writes, "Sticker guides make it possible for an amateur to sticker lumber as well as most experienced help. Warp is definitely reduced."

The piling of softwood lumber for kiln drying is generally mechanized to some extent. This is done to reduce piling costs and to facilitate the build-up of good kiln-truck loads. Even at the bigger mills, where sorters and stackers are used, constant attention is necessary to get good pilings. Sorters and stackers suitable for use by the smaller producers are being developed. Where unit-package handling is involved, one of the difficulties in package loading is in the transportation of the packages to the kiln, especially where fork lifts are being used. The tendency is for the stickers at the end of the package to fall out, or at least become misplaced. At some plants, where lift-truck transportation is fairly long over rough ground, the packages are strapped with metal bands to stiffen them, reducing the flare at the package ends which otherwise allows the end stickers to drop out easily.

The reporters were asked if "thin" stickers were being successfully used. Few plants are using stickers for piling lumber for kiln drying less than 3/4 or 7/8 inch thick. Breakage in handling of the stickers seems to increase greatly when stacking sticks much thinner than 3/4 of an inch are used. With stickers costing, as was reported, from 8 cents to 40 cents apiece, breakage becomes a factor. Species are selected for stacking sticks that appear to withstand the effects of reheating and redrying a number of times. At most plants, however, the species used is determined by what is available.

Unit-Package Handling and Kiln Drying: Package piling and handling with carriers and lift trucks seem particularly worthwhile when both air drying and kiln drying are involved at the same plant. Where package handling facilitates movement of lumber at softwood mills, conversion from kiln-truck piling to package loading of kiln trucks has occurred. If new kiln installations are being considered, the package-loaded, trackless dry kiln may be built. An advantage is the elimination of rails and kiln trucks. This kiln is satisfactory provided lumber can be stacked so that it can be properly baffled.

A reporter advises, "Package-loaded, trackless kilns seem to be worked out satisfactorily although some difficulty was originally encountered with high piles falling over in the kiln with shrinkage during drying. We do not have any data on temperature distribution or air velocities in these kilns."

Another writes, "Package type kilns have been built with the loads too wide and too high resulting in very nonuniform drying when lumber is dried green from the saw. For air seasoned lumber, such package kilns do excellent work, and, when properly designed, will do good work in drying green lumber." This problem of uniformity of drying results is reflected in another report: "I heard of one operator who was not getting uniform drying in his package-loaded kiln. The air travel was better than 20 feet across four packages. When drying green lumber, the center packages were not drying properly." A western reporter calls attention to the limitations of the trackless kiln, while another says, "Package-loaded trackless kilns of rather conventional design seem to be performing satisfactorily, but one kiln of this type is definitely not satisfactory; its lack of success, however, stems from the air circulation system and not because of the loading method." Perhaps one disadvantage of the package-loaded, trackless kiln is the time required to unload it and reload it. One reporter says that the times vary from 1 to 4 hours to get the kiln going again. He also points out that baffling is difficult, which results in the lack of uniform drying previously mentioned.

Where kiln trucks are loaded with packages to be dried in conventional, end-piled kilns, little difficulty is being experienced. Most plants using kiln loads, two packages wide with either two or three packages high, make a practice of spacing the packages at least 4 to 6 inches. This is good practice, as butted up packages sidewise might block off air movement across the packages as the layers of lumber may not be on the same level. A kiln designer makes this comparison: "We still believe that the end piled kiln will give more uniform and faster results than the very large package kilns, and they can be loaded by putting the load on kiln trucks by means of a fork lift. A great many plants do this and make a savings on labor and also have low building costs."

New Kiln Designs: The reporters indicated that no unusual kiln designs have recently been installed. Neither have there been any new developments in dry-kiln control instrumentation other than the availability of electrical instruments as an alternate for air-operated instruments. The furnace-type kiln with either direct or indirect heating, using gas or oil for fuel, continues to be of interest to a number of lumbermen and woodworking factory owners. These kilns are available as both package-loaded, trackless kilns or conventional, track-type kilns. They are available in either internal-fan or external-blower designs. The Division of Forestry Relations, Tennessee Valley Authority, Norris, Tenn., has designed a small, electrically-heated lumber dry kiln and reported on its cost of operation. Here and there, specially designed dry kilns are being installed to dry a particular wood product, but generally it appears that conventional designs of ventilated dry kilns with forced-air circulation and instrumented to give good control of dry- and wet-bulb temperatures and ventilation are mostly in demand. In the kiln-designing field, the prefabricated dry kiln is being planned by some manufacturers. These units can be furnished with an oil- or gas-fired source of heat energy as a package unit. With good insulation, tightness, and higher circulation rates, these units would compare favorably with the small German kiln designs, yet meet our own needs for much greater holding and output capacity.

Practically no information was obtained on kiln-drying costs. With greater interest in energy demands, some installations are being equipped with steam-flow meters, and the obtained data will indicate whether our kiln-drying methods are so wasteful of energy as compared with other methods and systems of kiln drying.

Special Drying Processes

Chemical Seasoning: During the 1930's, the basic principles of chemical seasoning, or the chemical pretreatment of green wood to minimize surface checking in subsequent drying, were developed at the Forest Products Laboratory, Madison, Wis. The method is applicable to such woods as oak and beech, which are difficult to season without surface checking. The experimental work demonstrated the value of common salt (NaCl) as a treating chemical, but its corrosiveness, particularly, was a distinct disadavantage. Lumber Cure, a product made by the Morton Salt Company, is buffered with chemicals to reduce the corrosiveness of sodium chloride yet not affect its usefulness as a chemical-seasoning agent. The reporters did not indicate a general use of the chemical-seasoning process to minimize surface checking in the refractory hardwods during seasoning. Lumber Cure, however, is being used in certain areas, and chemical seasoning as a process may be more widely used when surface-check-free hardwoods are worthy of the increased cost that the process requires.

Special Drying Methods: The only special drying process reported as being demonstrated at this time is the MacDonald drying process. The method is a boiling-in-oil process. Green southern yellow pine lumber is submerged in a solution of perchloroethylene containing other compounds. Pentachlorophenol may be added if preservative qualities in the dried product are desired. The perchloroethylene solution is heated, thereby conducting heat to the wood for the evaporation of water. No published report is yet available on the results of these pilot tests of the MacDonald process. Solvent-drying processes, differing in some respects from that developed by the Western Pine Association, have been demonstrated in southern California, apparently without success. The "lumber wringer" is being promoted in California, but claims as to the faster drying of redwood were not substantiated. The high-frequency dielectric-heating process for drying wood seems dormant insofar as commercial exploitation is concerned, although the Wood Hood Manufacturing Corporation, Lewiston, Maine, has recently announced the availability of a drying hood that can adapt high-frequency heating. An infrared drier for pine lumber in eastern Tennessee was dismantled. Interest in high-temperature drying is stimulating the possibility for the successful use of superheated-steam drying.

The Taylor–Colquitt Company, Spartanburg, S. C., is vapor drying crossties for preservative treatment and experimenting with vapor drying of lumber. Similar experiments in the vapor drying of lumber at the Oregon Forest Products Laboratory, Corvallis, Oreg., are also being continued. The Australians are also studying the application of the Taylor–Colquitt vapor-drying process to some of their woods, and have reported on the results of some of their studies. Vapor-drying equipment designed by Taylor–Colquitt is being used in Germany, France, South Africa, and New Zealand for pilot-plant and experimental work. The Brice Lumber Company, Archer, Fla., is vapor drying dimension lumber. The Long-Leaf Lumber Company, Atlanta, Ga., and Wood Preserving Service, Lake Charles, La., also have facilities for vapor drying lumber.

New drying processes that claim rapid drying with very little energy input and which dry the wood without shrinkage and stabilize it, always raise considerable doubt in the minds of wood technologists familiar with the structure of wood and wood-liquid relations as to the merits of such processes. The promoter of these new drying processes is then faced with the necessity of demonstrating his claims to the complete satisfaction of the lumberman as well as the wood technologist. British and German experimenters have recently become very interested in the effect of circulation on drying rates. The Germans are interested in the influence of turbulent flow on surface drying and the establishment of drying gradients. We can expect improvements in German kiln designs that presumably have much higher circulation rates than our conventional kiln installations. In the meantime, however, our earlier concepts of the value of forced-air circulation are confirmed by their studies.

Storage and Handling

Valuable lumber being air dried should be protected by pile roofs. Lumber that is piled for kiln drying ordinarily cannot be roofed, and the top layers of the kiln-truck loads will be badly degraded if exposed very long to sun and rain. A "green" shed is often constructed to provide this protection. The economics of such an installation have been debated for some time, yet the degrade losses due to direct exposure have not been extensively studied. Air-dried hardwoods piled for kiln drying at furniture factories are usually left out in the open, yet it has been reported that covered storage will pay for itself in 3 years. Data to confirm such statements are not readily available, yet many furniture manufacturers are constructing suitable sheds and buildings so that their incoming lumber is always under cover. An eastern reporter says, "More plants are already

building storage sheds awaiting kiln drying." This same reporter believes that the savings in a typical covered storage application will be 10 to 20 percent. A western reporter indicates that more plants are considering covered storage for green softwood lumber that is piled for kiln drying. Another writes, "I do not know of any plants that are planning to build green storage sheds, where data might be obtained on savings gained by covered storage, or of any heated storage for kiln-dried stock. The most common arrangement is to provide cover for dry stock but no cover for green stock. Some of the larger plants do provide green storage cover." When asked why one large western plant was laid out and designed and constructed with a battery of single-end kilns, the answer indicated that the investment in sprinkler systems for sheds had increased to the point where both green and dry sheds were not warranted. The green shed then was sacrificed in favor of cover for dry storage. The dry-storage shed also provided space for the stackers, unstackers, and dried truckloads of lumber, but truckloads of green lumber were stored in the open. Another interesting observation at a mill in eastern Washington was that bulk-piled lumber in carrier packages was stored in the open under water-sprinkler heads, until a kiln was ready for loading. The stock was then quickly piled and moved into the kiln.

Kiln-dried lumber, both hardwoods and softwoods, is usually stored under cover in most parts of the country. Many furniture manufacturing plants use heated storage conditions to keep the kiln-dried stock dry. Storage is often on kiln trucks, the loads being broken down only when the lumber is needed. Dried softwood lumber, on the other hand, is usually unstacked and stored in dry sheds. More recently, these sheds are designed for lift-truck, unit-package storage. Heating of these large dry sheds for softwood lumber is seldom done. Heated dry storage at hardwood fabricating plants, on the other hand, is effective, and, in addition, some furniture plants use heated storage rooms for the storage of machined, but unfinished, piece parts. Surprisingly, heated storage is seldom continued the year around, although the need to heat storage rooms during the warmer summer months is as essential as during the winter months.

General

Moisture-Quality Control: Statistical-quality-control methods provide a means of specifiying the moisture-content standards of the seasoning operation and adhering to these standards. In kiln drying, for example, the final desired moisture condition can be expressed in terms of an average and a variability statistic like the standard deviation. In unstacking lumber that has been kiln dried, moisture sampling plans can be put into effect to determine if the desired moisture levels of the average and the standard deviation have been met. The reporters indicated that the electrical moisture meters for wood are extensively used but the collected data are not often used to calculate moisture-quality values.

One reporter writes, "About the only quality control practiced is by moisture meter. However, I understand that the moisture content is critical in lumber used for laminations. Most plants use a moisture meter on every piece and discard those pieces above the moisture content specified."

Another western reporter states, "Several of the larger redwood mills use the Shewhart Control Chart for maintaining the quality of their kiln drying. One of the largest redwood mills has been using this system constantly for nearly 2 years."

Some of the western softwood mills have what amounts to a quality-control program for the stock being manufactured into cabinets at their plants; also, there are installations of Laucks Moisture Sentrys in operation in the area, which might be considered as steps toward quality control. Some manufacturers of hardwood flooring, hardwood dimension, and furniture have used statistical-quality-control methods to improve their kiln-drying operations and maintain the desired standards of dryness and uniformity of dryness. Interest in these techniques is expanding, and, with applied research being conducted to show how these methods can be adapted to the industry, much greater use of them can be expected.

Dry-Kiln-Club Activities: The dry-kiln clubs and associations offer a great opportunity to bring information to those who can make use of it immediately to the benefit of the industry. They provide a medium for the exchange of ideas and the discussion of wood-seasoning problems. Harry Rich, secretary of the New England Kiln Drying Association, points out that these organizations offer adult education in seasoning, which is desirable as only a few of our wood-using establishments feel they can hire a competent wood technologist. Rich further states, "Self-education is a wonderful thing, but it can be greatly expanded by providing incentive, developing imagination, and giving encouragement—three important aids to adult education." This, the kiln clubs and associations, with the support of the wood-producing and the wood-using industries, can do and are doing. These groups of kilnmen need to be encouraged to carry on or sponsor applied research projects. In this way, the value of new methods can be determined and new information developed. The Government laboratories and the forestry schools cannot possibly provide the information that is needed to best solve the seasoning problems that result from changing industrial conditions. The reporters were asked if the kiln clubs in their areas are active in sponsoring projects for future reporting at kiln-club meetings. An eastern reporter writes, "Kiln-drying club is active in area. Chief accomplishment has been improved management interest in problems of kiln drying and free exchange of kiln-drying information between kiln operators. No specific projects are being sponsored although they have progressed to the talking stage and action is hoped for within the year." Another writes, "The Southeastern Dry Kiln Club is very active in the area. They are holding two meetings each year and at the present time are sponsoring projects on the use of Forest Products Laboratory kiln schedules, types of stickers, cost of stickers and air seasoning practices." A western reporter states, "The West Coast Dry Kiln Club is active in this area. About six meetings are held each year, all of which are well attended.

The Southern Oregon-Northern California, Central California, Washington-Idaho-Montana, and the Eastern Oregon-Southern Idaho Dry Kiln Clubs have all been active.

The Redwood Seasoning Committee is sponsored by the California Redwood Association, and since its inception has been active in carrying on projects pertaining to the seasoning of redwood. The members of the Committee collect the information and report results at meetings of the Committee. The Committee meetings are very similar to kiln-club meetings; and this group joins six other western dry-kiln clubs to attend yearly joint meetings. This past May, a 3-day meeting of the seven western dry-kiln clubs was held at Eureka, Calif., with the Redwood Seasoning Committee acting as the host group. These joint meetings are well attended and the program includes the presentation of technical papers.

The western Canada reporter writes, "There is one active dry-kiln club on Vancouver Island. They meet twice a year and discuss various phases of kiln drying. One of the problems they are keenly interested in is the high cost of stickers." Eastern Canada does not have a dry-kiln club. The newest organization is the Wisconsin–Michigan Wood Seasoning Association. Its membership will represent mills and factories in the northern Wisconsin and upper Michigan areas.

Developments in Logging—1954[1]

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Discusses factors affecting 1954 market conditions, increased interest in use of wheeled tractors in skidding, and studies on debarking, whole-tree skidding, economic diameter limits for several species in any given stand, and new thinning methods. Contains bibliography of 1954 papers and publications in logging field.

Condition of the Industry

IT IS STILL TOO EARLY for figures on log and lumber production for 1954 to have been compiled, but our members in the various regions have submitted their estimates of the situation. In general, the year started out with a rather soft market, but by the end of the year, things had picked up to the point where production equal to or only slightly behind that for 1953 was estimated.

The rather prolonged strike in the western pine region caused some shift of emphasis to redwood logging, but the net result was a western cut approximately equal to the previous year's.

The west coast strike also had an effect on the eastern market, where the demand for local softwood lumber and dimension was stimulated. Construction activity in the east remained at a relatively high level, and the demand for hardwood construction timbers remained firm throughout the year.

In the south, the unusually dry summer permitted the logging of previously inaccessible swamps for pine, hardwoods and cypress. In the pulpwood producing regions, the use of dense hardwoods continued to increase, causing some slight modifications in methods of pulpwood harvesting.

Developments in Logging Equipment and Methods

As was pointed out in last year's report, it is difficult to pinpoint the exact year when any given piece of logging equipment makes its appearance. During the past year, however, the interest in the use of wheels instead of crawler tracks in skidding has increased to the point where it assumes prime importance.

As is usual in such instances, a combination of factors has stimulated this interest. For many years, the advantages of higher speed and lower maintenance costs have made wheeled skidding vehicles attractive. It took the development of practical, reliable four-wheel drive tractors, however, to offer any serious threat to the well-entrenched and highly useful crawler tractor. In addition, the increasing proportion of the log cut coming from second-growth stands in all regions, with its attendant lowering of average log size has given the wheeled tractor a chance to show its worth. To complete the string of circumstances which combined to make 1954 a year of interest in wheels was the southern drought which made the employment of wheeled tractors feasible in many localities for the first time.

It is not intended to leave the impression that the crawler tractor is out or even on the way out. While there will certainly be an area of overlap in which crawler tracks will be replaced by wheels, generally speaking, the two types of vehicle serve different sets of conditions, and it is quite possible that we will find the wheeled tractor making its greatest contribution in the opening up of stands hitherto economically inaccessible because of size or condition of the timber.

In the east and south, the wheeled prime mover is receiving the emphasis, while in the west, it is the wheeled arch. In the Lake States, there is as yet little interest in wheels. From Canada comes the report that emphasis continues on the construction of forest access roads. While logs from some areas will probably continue to be water-driven for some time, each year more and more logs are reaching the mill via truck.

Research and Development

Research and development continue on the wheeled tractor as well as on the perennial problem of de-barking. Debarking machines are definitely becoming more efficient, and chemi-peeling is finding considerable favor in some areas.

In Canada, a development of interest during 1954 was the application of whole-tree skidding, on an experimental basis, to the harvesting of pulpwood. The project is being carried out on a rather extensive scale, but as yet no definite results can be reported. Preliminary reports, however, indicate that the method may have real advantages in some areas.

Western loggers are showing an interest in efforts to determine economic diameter limits for the several species encountered in any given stand. They are particularly interested in the shifts which may occur at the lower end of the scale as between chipping a log or sawing it into common lumber, and at the upper end of the scale as between selling a log for low-grade peeler use or sawing into higher grades of lumber. Work of this nature in all regions could result in important economies in logging.

In the Lake States, a new method of hardwood thinning is being developed which, if the results of silvicultural studies now underway are favorable, will permit economical harvesting of thinnings from hardwood stands at a much earlier age than is now feasible.

Research and development in the form of "home-grown" machines and modifications of commercial equipment continues apace. The logger is an unusually ingenious fellow, and contributes constantly and importantly to the steady development of cost-cutting methods and equipment. The results of this work are reported competently by other sources on a periodic basis.

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[1] This Subcommittee Report was submitted through Fred C. Simmons, Chairman of the FPRS Logging and Milling Committee.

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Milling Developments During 1954[1]

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Reports on 1954 lumber production in major producing areas of U. S., effect of west coast strike on lumber industry, trend to mechanization and automation in sawmills, and important research results. Contains bibliography of 1954 literature.

ALTHOUGH MANY in lumber industry circles forecast a poor year for 1954 and it started off slowly, the outcome proved to be better than expected. The loss of production due to the strike in the Douglas fir region during most of the summer created a demand for the lumber from smaller mills in that region not affected by the strike and from mills in other sections of the country.

A definite trend noted throughout the country was that of mechanization in the sawmill. The replacing of manpower with automatic equipment is taking place in both large and small mills and this trend is likely to continue and intensify in the next several years.

Several important accomplishments in the field of research and development were noted in 1954 and will be available to the industry. Studies of the small sawmill and its production were conducted by federal and state groups and by trade associations.

Lumber Production

The general condition of the milling industry during 1954 varies considerably with the different sections of the country.

Production at Northeastern sawmills did not decline as much during 1954 as many had feared. Construction activity remained good, and the West Coast strike provided additional markets for softwood producers. Markets for hardwoods were generally poor, but picked up appreciably toward the end of the year for furniture, television cabinet stock, flooring and similar items. Construction timbers were in relatively good demand throughout the year.

Lumber production in the Central hardwood region was down slightly from the 1953 cut. This reduction was attributed to the slow furniture business and hardwood markets. Sales of Forest Service timber were also below the previous year.

In the Douglas fir region of the Pacific Coast, production was noticeably lower than 1953, largely because of the two and one-half month strike that closed a large segment of the industry during the summer months. Increased production by small mills that were not affected by the strike, and the return to production of many small portable mills, partially offset the loss of production by the large mills during the strike period.

In the redwood region, production for 1954 increased over that of 1953. The redwood market in the East increased substantially during the year, while export markets fell off.

The western pine market was favored during 1954 by an increasing volume of home construction and the strike which curtailed Douglas fir production.

Reports from Canada show the lumber production for 1954 to be above that for 1953. Exports of lumber continue to ride at a high level in contrast to the general Canadian export picture,

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where exports are down somewhat as a whole.

Changes in Equipment and Methods

In the South it is reported that many of the larger mills are installing or plan to install elaborate log handling systems of cranes, fork lifts, and log conveyor systems. Many log ponds are being replaced by this type of equipment. Several mills in the Northeast have installed mechanized log decks and automatic carriages during the past year.

In both the Northeast and South a definite trend toward use of gang mills for low grade logs has been noted. In the South some of the smaller mills are eliminating head rigs and putting their entire production through a round-log-gang. Larger mills are using a combination of conventional head rigs with cant or round-log-gangs. Several additional Northeastern lumbermen are investigating the possibilities of a sash gang for sawing low grade construction items from both softwoods and hardwoods.

A few new band mill operations have been started in the South, in most cases replacing existing circular mills. There seems to be no definite trend in this direction however.

On the Pacific Coast small and medium-size mills continue to show interest in converting circular head rigs to band and round-log-gang types. Several larger mills have installed special equipment for the sawing of small logs. Small band head rigs and light carriages have been added in some mills, while round-log-gangs have been installed to supplement the main headrig in others.

Small circular mills continue the slow process of mechanization. Lightweight mechanical turners are found in small mills in increasing numbers. More and more electric, hydraulic and pneumatic devices are being installed on small mill carriages.

In Canada, as in the U.S., the trend seems to be toward band and gang mills and away from circular mills.

Very little change was noted in the sawmill equipment and methods in the Central hardwood region. The majority of the sawmills are small, cutting less than 5 M board feet per day, and generally not in good mechanical condition.

In the South there has been a tremendous increase in the production of pulp chips. Practically all of the permanent type mills are installing debarkers, mostly of the mechanical type; and chippers. The smaller mills are using the cutter head or rotating chain type of debarker. One mill in Texas is installing two West Coast type hydraulic ring debarkers.

A new flail type debarker was installed by a Maine pine mill, along with a chipper, but was not in service by the end of the year. A New Hampshire pulpmill, with equipment for separating bark from wood in chips, started purchase of slabs.

New Installations

Two new bandmills were installed in Northern New York. One promptly burned out, but is to be replaced. At least three new firms, using short log bolters to make hardwood dimension stock for the open market started business in the Northeast. Their success will be watched closely, as up until now not much of an open market for this class of material has been established. The existing mills installing such equipment and new firms going into production will have to develop market and price structures if they are to be successful.

Two relatively large mills have been established in the South during the past year. The Allison Lumber Co. of Bellany, Ala. and the Kirby Lumber Co. of Silsbee, Texas. Other installations include about forty Swedish type gangs that have been set up throughout the region, during the past several years.

In the Central hardwoods, The National Distillers' Company has installed two stave mills in Dent County, Missouri during the past year to cut white oak in that area.

An interesting new sawmill installation in eastern Canada during the past year was erected in northern Quebec. This mill employs a twin circular headrig followed by a gang saw. Small size logs are slabbed on two sides simultaneously by the twin-circular head rig and the resulting cant is rotated 90° and run through the gang saw. Actually, up to four or five of the cants are put through the gang at one time. Any heavy slabs produced by the headsaw are sent to a band resaw. An edger and trim saws complete the operation. Although only recently installed, daily production amounts to about 55 M fbm with 18 men in the mill and is expected to reach 65 M fbm.

Research and Development

The State University of New York, College of Forestry broke ground in September for its new wood laboratory building which will house its new completely instrumented experimental sawmill.

The study of sawmill residues and their disposal at sawmills in Maryland, conducted cooperatively by the Maryland State Department of Forests and Parks and the Northeastern Forest Experiment Station was completed and will be published early in 1955. This study shows that Maryland sawmills, despite their inaccuracies and the small logs they are sawing, are getting more of their raw material into their primary product than any other wood using industry in the State.

The University of Southern Illinois, in conjunction with the Central States Experiment Station, is carrying on experiments in utilization. A complete woodworking plant is being installed at Carbondale, Ill. The University of Illinois at Urbana and Purdue University at Lafayette, Indiana, are both carrying on experiments in wood preservation, log grading and grade recovery.

The Ford Motor Company Funds gave to the Michigan College of Mining and Technology at Houghton a sawmill at Alberta, Michigan, together with the town and about 17,000 acres of timber for their Forestry School.

A study on "Power Requirements at the Headsaw" was conducted by the Ottawa Laboratory of the Forest Products Laboratory of Canada. Besides dealing with actual power requirements by the headsaw of various depths of cut and in various species, the studies also showed the relationship of saw speed and carriage speed to power requirements.

An adjustable sawmill gauge was designed and built by the Ottawa Laboratory to eliminate play in the carriage setworks and backlash between the rack and pinions. (reprints available from the Forest Products Laboratory of Canada in Ottawa).

The Ottawa Laboratory is also conducting studies on short-log bolters to compare the efficiency of operation of these machines to that of a conventional sawmill in the production of furniture stock. The results will be reported at the FPRS National Meeting in Seattle in June, 1955.

A much greater interest has been shown in Sawmill Engineering and Research by even the smaller mill men in the West. At least one new Engineering firm specializing in sawmill layout and building has been started and several expansions of existing firms have been reported. A tendency to try new mill floor plans has been noted, with mills getting away from the conventional designs in an effort to increase productivity.

Meetings and Conferences

In the South it is reported that new associations are being formed from local level to state level in promoting interest in lumber manufacture and lumber products. Small group meetings are promoted by the various state forest commissions, the Tennessee Valley Authority and others.

The Central States Annual Logging and Milling Show was held near Rock-

ford, Illinois. A series of three two-day small sawmill clinics was held in New York State under the auspices of the State University College of Forestry. These were followed by two one-day sessions in Vermont under the auspices of the Vermont Forest Service.

The Governors of the States of Washington and Oregon held their annual Industrial Safety Conferences in their respective States. The Conferences dealt with safety in all industries within the State. The large attendance in the sawmill, plywood and logging sections showed the trend of mill men and loggers in taking a greater interest in safety programs for their companies in an effort to make them safer and to reduce accidents.

Sawmill Operators' Panels were presented at Willamette Valley Logging Conference, Eugene, Oregon April 29, 30 and May 1st, and the Redwood Region Logging Conference, Arcata, California November 5 and 6 upon the suggestion of the sawmilling subsection of the FPRS Logging and Milling Committee. With Milton H. Mater acting as moderator and a group of well known speakers, the panels provided a much needed opportunity for Pacific Northwest mill operators to discuss technical problems.

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Packaging Research and Development

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Discusses history of packaging industry for past 50 years, development of new container types, and effect of World War II packaging research on industry. Describes most important recent developments in packaging and contains bibliography of references and publications.

THE PACKAGING INDUSTRY, whose sales are now 10 billion dollars annually, supplies more than 300 billion packages of all types each year. The field of packaging includes all the materials and the processing required to protect material during manufacture, shipment, and storage prior to ultimate use. It involves cleaning, drying, selection and application of preservative methods, unit packaging, cushioning, blocking and bracing, interior containers, barriers of all types, intermediate containers, shipping containers, identification and marking, reinforcement strapping, carloading, and handling of packaged goods. For consumer goods it also includes all the factors that enter into the problem of sales appeal and consumer acceptance.

Historical Background

Although containers have been used as long as man has transported and stored goods, it has only been within the last 50 years that their characteristics have been investigated scientifically. Wood was for many years the primary material employed for shipping containers and it was so plentiful and cheap that boxmakers employed only the higher grades and the most desirable species. Little attention was given to designing boxes so as to obtain maximum performance for a minimum of material.

One of the earliest research projects was the study of nailed-wood boxes started at the Purdue University laboratory of the Forest Service in 1904. These early investigations clearly demonstrated that the details of construction had far greater influence on the overall strength of a box than the grade or species of wood used, and indicated the need for more extensive studies. Shortly after the Forest Products Laboratory was established at Madison, Wis., in 1910, an investigation of wood containers was started and enough information had been gathered by the time we entered World War I that workable specifications for wood containers could be prepared. These specifications allowed the use of many different species, limited defects, and provided stronger containers with considerably less material than had been used previously.

The last 50 years has also been the period of development and widespread use of other types of containers and in particular fiberboard containers. Corrugated fiberboard containers as we know them today had their origin with a patent issued in 1871 for a single-faced corrugated sheet that was intended for use as a protective wrap for bottles. Later, a second liner was added and the first corrugated fiberboard box appeared in 1894. By 1910 railroad acceptance of the containers had been obtained and from that time on the growth of the fiberboard box industry has been phenomenal. Today almost 7 million tons of container board are consumed annually for the shipment of a wide range of commodities from fruits and vegetables to heavy and large refrigerators and ranges, and fragile television sets.

Prior to World War II, research in packaging was generally confined to the exterior containers in an attempt to provide low cost, strong, lightweight containers that required little storage space prior to use. This research resulted in the development of wirebound, plywood, and several combination wood and fiber containers that were readily accepted and are extensively used today. As an example, in the last 20 years the production of wirebound crates for the shipment of fruits and vegetables has increased to over 100 million crates annually. This increased interest in containers was evidenced by the establishment of the Association of American Railroads Freight Loading and Container Section, the packaging division of the American Management Association, the D–10 Shipping Container Committee of the American Society for Testing Materials, the Container Committee of the Technical Association of the Pulp and Paper Industry, and numerous associations such as the National Wooden Box Association, Wirebound Box Manufacturers Association, and the Fibre Box Association. During the period prior to World War II, the first industry, association, and commercial container testing laboratories were established.

Packaging was one of the most important and least publicized phases of World War II. Because of the far-flung battle fronts, the war was largely one of material logistics and food and material had to be protected for any climate. Vast quantities of container materials were consumed. For example, in 1944 17 billion board feet of lumber was used for packaging. This was approximately half of the total lumber production for that year. Similar demands were placed on other container materials which created scarcities and led to the development of substitute containers and improving the existing materials and containers. Possibly the greatest accomplishment in this field was the development of the V- and W-fiberboards that had excellent wet strength properties and were employed in millions of containers for the shipment of subsistence goods. Another excellent product that was produced in astronomical quantities was the asphalt impregnated fiberboard, spirally wound, metal-end ammunition containers.

It was during the war that numerous government and industry packaging research laboratories were established to fight the battle of corrosion and developed means of providing physical protection for war materiel. The specialized field of corrosion protection was recognized and accelerated research programs in this field resulted in the modern methods of preservation. These methods involve greaseproof and moisture-proof barriers, preservative oils and greases, desiccants, vapor-corrosion inhibitors, waxes, and solvents.

Physical protection requirements led to new concepts in cushioning, blocking and bracing, crate construction, and pallets. During the war the forests provided by far the majority of cushioning

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material required in the form of cellulosic wadding and wood fiber felt. Rubberized animal and vegetable fibers, glass fiber, resinous foam plastics, sponge and foam rubber, and other water-resistant cushioning materials found limited applications in the protection of aircraft instruments and electronic gear.

New Crate Types

The overseas movement of large military items necessitated considerable research and development work on both open and fully sheathed crates. The demountable type crate, assembled with lag screws, was developed during this period and found wide use in the shipment of aircraft and aircraft components. This and other reusable type crates were developed for aircraft and vehicle engines, aircraft turrets and fuel tanks, and many other items that were produced in large enough quantities to justify their use. All of these crates employed a minimum of material and were required to successfully withstand a severe test program before acceptance.

Although pallets were employed in limited quantities prior to the war, the need for a faster means of moving the large quantities of war materiel really provided the spark that led to the present wide use of pallets. The National Wooden Pallet Association estimates that there were only 16 wooden pallet manufacturers in 1939, whereas today there are over 1,000 manufacturers producing approximately 20 million pallets annually. Although pallets are made from wire, metals, and fiberboard, the majority of them are made from low grade lumber that might otherwise be classified as waste. Wirebound pallet boxes are extensively employed for bulk shipments of fruit and vegetables from the field to the packing houses and in the industrial and military fields for weights of 2,000 to 4,000 pounds.

The great amount of interest in packaging generated during the war carried over into the postwar period. Much of the research conducted under wartime pressure was examined and led to further research and to the development of standard methods of test. The Department of Defense appreciated how ill-prepared they were for the war and have maintained their packaging staffs and laboratories. The Packaging Institute, Inc., born as a wartime service to the government, also continued their surveys and research for the advancement of better packaging in order to promote a more sound business economy.

Several colleges realized the need for specialized training in packaging and introduced packaging courses into their curriculums. A group of industrial packaging engineers formed the Society of Industrial Packaging and Materials Handling Engineers that now has thousands of members in local chapters throughout the United States. Manufacturers examined their packaging and found that great savings could be made by adopting modern packaging and materials handling methods. The manufacturers of porcelain goods voluntarily established the National Safe Transit Committee to improve the packaging within their industry.

In the consumer field, the rapid increase in supermarkets and self-service stores compelled manufacturers to package products that were formerly sold in bulk, and to improve their existing packages so as to be more attractive and provide greater protection to their products. Many wartime barrier materials were adopted for consumer packages and continued research resulted in the development of new barriers that were not only efficient, but also were more attractive and could be easily printed.

Recent Developments

As stated earlier, this report will not attempt to discuss all of the developments in the packaging field during the past few years. The list of packaging references and publications, also prepared by this committee, will provide references to many other new developments that are not included in the following discussion:

Pallets: One of the most important recent advances in the wooden pallet industry was the acceptance of pallets made from softwood species. This has provided new outlets for utilizing low grade material which would otherwise be wasted, and the use of softwoods has in many instances resulted in lower tare weight of the pallets. Research has also demonstrated the advisability of using dry lumber, providing adequate fastenings, and the use of wood preservatives for pallets employed out-of-doors, or where they are subjected to wide variations in moisture.

The last few years have been a period of rapid development of the low cost disposable fiberboard pallets. The latest of these weighs less than 3 pounds, supports over a ton of bagged material, and consists of a deck sheet of 90-pound basis weight kraft paper containing melamine resin and two paperboard tubes. Two ends of the sheet are folded back and bonded with a wide strip of glue, leaving a sufficiently wide opening for insertion of the tubes. Special bayonet type forks may be attached to any type forklift truck to slip into the tubes for lifting the palletized load.

Another new development in the fiberboard pallet field is the square post pallet. The posts consist of properly scored sheets of double-faced or double-wall fiberboard that are formed into posts at the user's plant. Adhesive is then applied to the ends of the posts for attachment to the double-faced or double-wall fiberboard top and bottom deck.

A combination wood-fiberboard pallet is currently being developed that shows considerable promise. The posts or spacers consist of three pieces of 1-inch lumber that are nailed or glued together in the form of an "H" which is then wrapped in double-faced fiberboard. The single deck can be any suitable panel material ranging from plywood or paper-overlaid veneer to hardboard or double-faced fiberboard and is nailed to the posts. The advantage in employing wood in the posts is that high stacking strength is obtained under moist conditions, such as in refrigerated storage. Yet the pallet is much lighter and cheaper than most conventional wooden or metal designs.

Air Cargo Containers: Tare weight is of the utmost importance in shipping by air since the aircraft capacity load is determined by weight rather than by volume. Since the maximum weight capacity of aircraft is low compared to other types of transportation and the cost of aircraft operation is high, the cost of air transportation per pound is relatively expensive. Lightweight fiberboard and combination material containers recently have been developed for air cargo shipments. A container selection chart has been developed to guide the shipper in the proper choice of container for air shipment. This chart appears in the USAF Technical Order 00–85–9 dated October 1953. For large items such as aircraft control surfaces, a two-way container has been developed that consists of a fully or partially sheathed exterior container and a lightweight interior frame that contains the item. The interior frame has a minimum of material consistent with the protection required for air shipment and easily slides into the exterior container for surface shipments. Through extensive research it has been possible to provide two-way designs for military shipments that do not have any more tare weight than the standard military surface containers. Thus considerable savings can be obtained in the air shipments without an increased transportation cost for surface shipments. All of these containers are designed so that they can be reused many times.

Paper-overlaid Veneer: Increased interest during the past year was noted for this product that consists of a single sheet of veneer overlaid on each face

with paperboard. The products from the various producers are not uniform in that the cores of either softwood or hardwood species vary in thickness from 1/16 to 3/16 inch; the paper overlays are either Fourdrinier or cylinder kraft of different weights and thicknesses ranging from 0.016 to 0.030 inch, and various types of glues are employed in fabrication. One product has the core distended by slitting the wood parallel to the grain without removing any wood substance. This process is intended to prevent warping of the panels. Another product employs asphalt impregnated overlays, while still another wax coats the overlays after fabrication. Methods of fabrication also differ. For instance, one manufacturer uses a continuous process and laminates the overlay to the veneer as the veneer comes from the lathe and prior to drying.

Paper-overlaid veneer to date has found the greatest application in standard styles of cleated-panel boxes. Considerable research is currently underway, however, to develop special types of overlaid veneer containers for the shipment of agricultural products. One of these containers, already developed and in use, has two metal straps embedded in the material which acts as a hinge and reinforces the nailing of the overlaid veneer to the cleated ends.

Fiberboard Containers: New types of fiberboard containers for special applications appear daily. Much research is currently underway to expand their use in the shipment of produce from Florida, California, Washington, and Arizona. Particular interest is shown in the shipment of lettuce, citrus fruits, apples, berries, plums, avacados, cherries, pears, and tomatoes. The greatest volume use of fiberboard in this field is at present for lettuce and lemons, although considerable quantities are also employed for apples, oranges, and tomatoes.

Current research involves not only containers but also related investigations which extend into the fields of agriculture engineering and plant physiology. New methods for packing produce in these containers are being investigated and established data on shipping temperatures, ventilation, and carloading are being re-examined.

The competition between wood and fiberboard container is primarily one of economics, not only in the initial cost of the containers, but also in handling costs and shipping charges. The performance of the fiberboard containers has generally been found to be acceptable except in those instances where they have to be exposed to prolonged moisture as in some types of storage. Also, there has been some question about their use with some types of produce in which there may be a reaction between the produce and the fiberboard, especially where the fiberboard has been treated to increase moisture resistance or to inhibit mold.

A recent interesting development in fiberboard shipping containers is the tear-tape opening device. It consists of a strip of pressure-sensitive filament tape applied to the inner liner of the container blanks prior to taping the manufacturer's joint. In the closed box it is hidden except where it extends out from under the manufacturer's joint. Opening is accomplished by merely pulling the end of the tape which cuts through the board in the side and end walls so the upper portion of the box can be lifted off.

Glass-reinforced Paper: A good example of the increasing trend to combine forest products with other types of materials is the glass-reinforced paper. The glass scrim employed for reinforcement in one product is not woven, but is made by coating the longitudinal yarns with a hot melt adhesive and applying the cross yarns while the adhesive is still molten. The glass scrim can be produced in various sizes of mesh and size of glass yarn. It can be sandwiched between different weights and types of paper or attached to only one sheet of paper, depending upon the end use requirements. Research to date has involved applications for single and multiwall bags, solid and corrugated fiberboard boxes, pallets, tarpaulins, case liners, and grain doors. Probably the greatest success has been in the bag industry where the high tensile strength of the reinforcing fibers can be utilized and where these fibers prevent tearing across the bag surface.

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Highlights in the Chemistry of Lignin, 1943-1954[1]

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A review and discussion of advances in the chemistry of lignin by study of model compounds and the chemistry of sulfonation, oxidation, alkali cleavage, changes occurring during isolation, and biological synthesis of lignin-like polymers.

PROGRESS IN THE CHEMISTRY of lignin has been greatly retarded by the complexity of the lignin molecule. In the 10-year period immediately before 1943, there were four discoveries that increased significantly our knowledge of the chemistry of lignin. These were the isolation of a small amount of an alcohol-soluble lignin directly from wood at low temperature and without the use of chemical agents that may alter the structure of lignin (1), the discovery of small amounts of several water-soluble monomeric compounds related to lignin in the ethanolysis products of wood (2), the discovery that lignin in spruce wood gave high yields of vanillin when heated at 160° with nitrobenzene and alkali, (3), and the discovery that hydrogenolysis of methanalysis-lignin gave high yields of compounds related to 2-methoxy-4-propyl phenol (4). A handicap at that time was the lack of information on compounds related to lignin.

Prior to this period, there had been a difference of opinion among investigators as to the aromatic nature of lignin. As a result of the discoveries, a polymeric aromatic structure for lignin, composed of building units of derivatives of 2-methoxy-4-propyl phenol, was accepted by most investigators. The period 1943 to 1954 has been one of great activity in the field of lignin chemistry. A review of this work contains about 600 references (5). These researchers have been aided by several reviews and texts (6, 7, 8, 9) describing the chemistry of lignin.

In the past decade, seven fields of research stand out as major contributions. 1. The increase in the knowledge of compounds related to lignin through the synthesis and study of many model compounds has been of great importance. 2. Chromatography as a means of separating lignin preparations into various components should lead to further advances by making it possible to study pure compounds. 3. Study and interpretations of the bisulfite reaction give an insight to the chemistry of sulfite pulping. 4. Changes that have been found to occur in lignin as a result of the various methods of isolation may lead to a discovery of the mode of linkage in the lignin molecule. 5. Lignin in wood subjected to the action of carbohydrate-destroying organisms is changed so it becomes soluble in organic solvents. 6. Simple compounds having structures related to lignin have been converted to carbohydrates by bacteria, indicating a biological relationship between carbohydrates and lignin. 7. Lignin-like amorphous polymers have been produced from lignin model compounds by the action of oxygen in the presence of enzymes present in mushroom extract and in growing plant tissue.

Model Compounds

Studies of the reactions of model compounds have contributed to an interpretation of the reactions of lignin. Much more research on the chemistry of compounds related to lignin is needed before it will be possible to account for all the reactions of lignin.

Ethanolysis Products as Model Compounds: Hibbert and students (10) found that small amounts of low-molecular-weight lignin products were produced by ethanolysis of wood and lignin. Some parts of the ethanolysis reaction appeared to be reversible. Lignin obtained by ethanolysis gave additional low-molecular-weight compounds when treated again with ethanol and HCl. Ethanolysis products polymerized in the presence of ethanol and HCl. A part of the lignin was resinified to a product that could not be depolymerized by ethanol and HCl. Ethanolysis products were 3 hydroxy-1 (4-hydroxy-3-methoxy phenyl)-1 propane derivatives and were obtained in quantities representing 4 to 8 percent of the lignin. On oxidation with nitrobenzene and alkali, high yields of vanillin or its dervatives were formed. Many of these derivatives were synthesized and their reactions studied. They were methylated and ethylated. Treatment of the ethanolysis compounds with ethanol and HCl gave an amorphous polymer resembling lignin. The ultraviolet spectra of several ethanolysis products and related synthesized compounds was similar to that for lignin. The properties of 3-hydroxy-1 (4 hydroxy-3-methoxy phenyl) 2-propanones lead these investigators to believe this compound was a lignin progenitor. The ethanolysis of this compound to lignin ethanolysis products and lignin-like amorphous polymer was carried out by Gardner (11).

Brom Compounds: When spruce lignin is brominated and the product oxidized to vanillin derivatives, only the 6-brom derivatives were found. When model compounds such as coniferyl aldehyde were brominated, 5-brom compounds were produced, indicating that the 5 position in lignin may be filled. No research on the bromination of 5-substitute model compounds was reported.

Sulfonation of Model Compounds: Sulfonation of model compounds has revealed that alpha-substituted benzyl alcohols are sulfonated (12). The presence of a para-hydroxy group makes sulfonation easier. Methylation of the para-hydroxy groups hinders sulfonation (13). Lignans such as pinoresinol, which is present in extractives of wood and contains an ether group in the alpha position, were sulfonated and behaved in a manner similar to lignin (14). Aromatic keto and hydroxy polyethers were changed to alcohols and sulfonated by sulfite pulping conditions (15). Substituted acetoguaiacones were converted to polymerized amorphous sulfonic acids by sulfonation. Polymers of aromatic keto and hydroxy polyethers were 90 percent sulfonated at pH 1.7 to 1.8.

When a carbonyl group is in conjugation with a double bond, the compound was readily sulfonated while ketols in 1, 2 position do not sulfonate (16). Sulfonation studies on model compounds indicate that the easily sulfonated groups in lignin are benzyl

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alcohol-type hydroxyls or ethers that are readily changed to hydroxyl groups by the conditions of sulfonation and then sulfonated.

Erdtman (17) found that the sulfonation of lignin was a two-stage process, one involving the sulfonation of lignin at pH 4 to 6 without producing a soluble product. The lignin became soluble after hydrolysis and contained one sulfur for about 4 methoxy groups (18). Further sulfonation of the hydrolyzed product at pH 5 gave a product with 1 sulfur for about 2 methoxyl groups. Sulfonation at pH 1.8, hydrolyzed and sulfonated the lignin to a product with 1 sulfur for about 2 methoxyl groups. Decayed wood in which carbohydrate-lignin bonds have been exposed to hydrolytic enzymes is sulfonated to the higher sulfur content at high pH (20). On the basis of a study of model compounds, it is proposed that the groups sulfonated at pH 4 to 9 represent sulfonation of free benzyl-alcohol type groups or of benzyl-alcohol type ethers of the type present in pinoresinol and olivil. The additional groups sulfonated at pH 1.8; or the groups sulfonated after hydrolysis of the low sulfonated product, may be the points of union of lignin with carbohydrates of wood and represent substituted benzyl alcohol-carbohydrate ethers that must be hydrolyzed at a low pH before becoming available for sulfonation (19). It should be possible to prepare model compounds with the two types of ether linkages and submit them to sulfonation for confirmation of these proposals.

Open Chain Model Compounds: Oxidation of several types of model compounds with nitrobenzene and alkali has provided information relative to some of the types of linkages in lignin. Oxidation of spruce wood with nitrobenzene and alkali has yielded an average of 31.6 percent aldehydes based on the methoxyl (21). Vanillin represented about 90 percent of the aldehydes. Hardwoods, such as birch, yielded 47.0 percent aldehydes of which about 75 percent was syringaldehyde.

Many compounds having a 4-hydroxy-3-methoxy phenyl propane structure with several types of substitutions on the propane side chain, when oxidized with nitrobenzene gave high yields of vanillin (22). Yields were 80 to 90 percent if an alcohol group or an unsaturated linkage was present on the alpha carbon atom. Keto or saturated hydrocarbon linkages gave 17 to 30 percent yields. Polymers of compounds with alcohol or ether groups in alpha position gave yields of 70 to 87 percent of vanillin. Compounds with substitutions in the 5-position of the phenyl ring gave little or no vanillin, but did give low yields of 5 formyl vanillin and other 5-substituted derivatives. Compounds with methylated para-hydroxyl groups yield little or no vanillin. Condensed structures (23) in which condensation occurs as ethers in the side chain, such as pinoresinol, yield 31 percent vanillin, and olivil, 83 percent vanillin. The latter is an ether between two alpha hydroxy groups. Carbon-to-carbon condensations of the type found in conidendrin yield no vanillin.

On the basis of the yield of vanillin from model compounds, it is proposed that spruce lignin contains 40 to 50 percent of polymers of compounds that do not have additional substituent groups in the 4-hydroxy-3-methoxy phenyl grouping. Condensation in this part of the molecule must be through the phenolic hydroxyl or the side chain, as in the lignans. This proposal appears to be confirmed by the yield of products from lignin-sulfonic acid by metallic oxide oxidation (24) and of products by hydrogenation (25).

Five-Substituted Model Compounds: The yield of 5-substituted products from 5-substituted model compounds by nitrobenzene-alkali oxidation is low. On the basis of the yield of products from model compounds it is possible that 30 percent or more of the lignin molecule is polymerized by carbon-carbon condensation in the 5-position in the 4-hydroxy-3-methoxy phenyl group. Oxidation of lignin with potassium permanganate also gives low yields of 5-substituted compounds (26). This may, however, be due to the resistance of this type of linkage to oxidation. Hydrogenation of lignin (27) yields 5-substituted phenolic compounds, indicating that this linkage is present in the lignin molecule. Further work on model compounds is needed to gain more information on the yield of products and reactions of 5-substituted derivatives and to determine if the 5-substituted products result from the action of reagents on lignin.

Alkali Cleavage of Model Compounds: Vanillin, acetaldehyde, and formaldehyde are present in the cleavage products when lignin is treated with alkali. Adler and Haggroth (28) found that lignin sulfonic acid, alcohol-soluble lignin, various isolated lignins, and spruce wood gave vanillin and acetaldhehyde when heated with alkali. Lignins isolated by acid or alkali gave less. Sulfonation appeared to activate the cleavage. They conclude this is a confirmation of a coniferyl structure for lignin.

Kratzl and coworkers (29) carried out experiments on lignin products and several lignin model compounds to determine the yield of cleavage products. Cinnamic aldehyde hydrosulfite and cinnamic aldehyde were cleaved by a reverse aldol cleavage to benzaldehyde and acetaldehyde. The benzaldehyde was converted to benzyl alcohol and benzoic acid by Cannizzaro reaction. Vanillalacetone and its bisulfite derivative were cleaved by alkali to vanillin and acetone. The bisulfite derivative gave the higher yields. Compounds with unsaturated groupings or alcohol groupings or sulfonated alcohol groupings on the alpha carbon of a benzyl group gave the aldehyde. Those with carbonyl group on the alpha carbon atom gave acids. Arylvinylketone yielded formaldehyde and a ketone by reverse aldol condensation. The yield of cleavage products from lignin-sulfonic acid in the presence of 10.7 percent sodium hydroxide is 1 mole of acetaldhyde for 15 methoxyl groups and 1 mole of vanilin for 21 methoxyl groups. The yield from 1 mole of methylconiferylaldehyde was about 0.75 mole of acetaldehyde and 0.55 mole of veratric-aldehyde. On the basis of the model compound, there may have been 1 mole of coniferyl aldehyde type grouping capable of being cleaved by alkali to about 10 methoxyl groups in lignin. Those capable of being cleaved to formaldehyde are less. Alkali-cleavable groups appear to be masked or destroyed when lignin is isolated by strong acids.

Color Reactions of Model Compounds: When wood is treated with a phenol in the presence of strong hydrochloric acid, a color is produced. Adler and coworkers (30) studied the color reactions of a number of lignin model compounds. They found that veratralaldehyde, methylconiferylaldehyde, and coniferylaldehyde gave color reactions similar to spruce wood when treated with phloroglucinol and hydrochloric acids, and compounds without the conjugated side chain, such as eugenol and methyl eugenol, did not. The intensity of the color developed indicated the presence of one such conjugated group for about 40 methoxyl groups. Pew (31) sought to establish the nature of the color group. Condensation of spruce lignin with resorcinol produced a color of the same wave length as reduced 4′,7-dihydroxy-3′-methoxy flavanone, 2′,4, 4′trihydroxy 3-methoxy chalcone reduced by lithium aluminum hydride and the same color as coniferylaldehyde condensed with resorcinol. A yellow color is produced by the action of strong acid alone on wood. This color corresponds to the color produced by coniferyl aldehyde type compounds. This color production is believed to indicate the presence of the conjugated structure in the side chain. It is estimated from the intensity of the color produced that one such grouping to 30 methoxyls is present in the lignin molecule. After the wood had been in contact with hydrochloric

acid for some time, a green color developed. This was due to a blue color and agreed with the color produced by condensation of a coniferyl aldehyde with a guaiacyl group.

Mrs. Aulin–Erdtman (32) and Goldschmid (33) compared the shift in the ultraviolet light absorption of various phenols and lignin when the neutral solution was measured against an alkaline solution. The shape of the curve indicated the presence of phenolic nuclei in lignin. The increase in the extinction coefficient in the wave length in the region of maximum absorption of the phenolate ion was used as a means to measure the amount of phenolate ion. Goldschmid's method indicated the presence of 1 phenolic hydroxyl to 2.1 methoxyls in alcohol-soluble hemlock lignin. High-molecular-weight lignin sulfonic acid contained 1 phenolic hydroxyl to 4.2 methoxyl groups. Swain (34) has found that conjugated groupings play an important part in such color shifts and that all phenolic compounds do not behave the same.

Changes Occurring in Lignin Due to Isolation Methods

Recent experimental work has brought to light changes in the chemical structure of lignin that result from the method of isolation. Knowledge of lignin models has not developed so that it is possible to interpret these changes.

Lignin isolated by the use of concentrated hydrochloric acid (35) yields 6.85 percent vanillin, compared with 27 to 28 percent (21) from untreated wood. Methylation of the lignin before nitrobenzene-alkali oxidation resulted in low yields (36) of vanillin, vanillic acid, parahydroxy benzaldehyde, and an unknown substance. Pew (31) noted that concentrated hydrochloric on spruce lignin produced a compound with a blue color characteristic of phenol-type condensation products. Richtzenhain found evidence for condensation in the 6 position of the phenyl propane group in spruce wood treated with concentrated hydrochloric acid that was not shown in untreated wood. These changes indicate that hydrochloric acid causes condensations in the lignin. The low yield of vanillin indicates that the open side-chain structure, which appears to be necessary for vanillin production, has been condensed with the aromatic part of the molecule.

Lignin isolated by the use of ethanol and hydrochloric acid is subject to some of the same conditions as that isolated by concentrated hydrochloric acid. Depolymerization of lignin occurs, yielding 4 to 8 percent of the lignin as monomeric compounds (37). Treatment of the depolymerized products with acid causes them to condense to lignin-like polymers. It is possible that some of these monomers recombine during the isolation procedure to form polymers with a different structure from that present in wood. Two ethoxy groups for each 40 to 50 carbons are introduced. These are removed again by treatment with strong hydrochloric acid. As further evidence of rearrangement, an increase in the amount of acetic acid on chromate oxidation was observed in ethanol–HCl lignin (38), but the increase was not as great as that found in lignin isolated by dioxane and hydrochloric acid (39). One of the great changes that occurs is the change in solubility. It is not known if this is due to changes in structure or to formation of some type of ion. Hydrogenation of methanol or ethanol lignin gives high yields of monomeric products. Further study of the hydrogenation of wood and further study of degradation products of ethanol- and methanol-lignin should yield valuable information on the structural units of lignin.

"Native" lignin isolated in small yield from wood by extraction with ethanol at room temperature has been assumed to be identical with lignin in wood because it gave the same color reactions as wood and because it reacted with sodium bisulfite and thioglycolic acid in a manner similar to lignin in wood. Most of the lignin in wood, however, requires a low pH (1.8) to convert it into soluble lignin sulfonic acid, whereas "native" lignin dissolves readily at pH 5 to 7. Native lignin has a lower methoxy content than cupra-ammonium lignin or sulfuric-acid lignin. This is assumed to be due to the loss of some constituent from lignin during the cupra-ammonium or sulfuric acid treatment. However, it has been shown that "native" lignin is not a uniform substance. Hess (40) separated spruce native lignin into fractions with molecular weights ranging from 2,800 to 6.700, methoxyl content of 14.1 percent to 15.7 percent, and carbon content of 61.78 percent to 67.27 percent. Buchanan, Brauns, and Leaf (41) found no well-defined maximum for a pure substance under ultraviolet light. Chromatographic separation of "native" lignin from blackwattle showed it to contain dark-colored compounds in addition to the lignin (42).

Lignin of wood becomes alcohol-soluble after wood is exposed to wood-rotting organisms (43). This material is similar to native lignin. It has a methoxyl content lower than that found in lignin from untreated wood (44), and pine lignin was shown by electrophoresis to be a mixture (43). Leopold (45) found a loss in methoxyl content and vanillin production from lignin in wood decayed by brown rot. This loss of vanillin-producing groups may account for the low methoxyl in lignin in rotted wood. Native lignin may have been the result of similar enzyme activity. The oxidation similar to that of 5–6 dihydroxy indoles (46) and of catechols (47) by air may account for the loss of methoxyl during the enzyme activity. Isolation of a pure lignin by chromatography and the determination of its composition and properties should be helpful in the study of "native" lignin.

The use of alkali to isolate lignin causes several changes in lignin. Acetaldehyde and formaldehyde are cleaved from the side chain; some vanillin is cleaved from the molecule. The number of phenolic hydroxyl groups increases from 1 phenolic group for 2 to 3 methoxyl groups to 1 phenolic group for 1 methoxyl group. Fractionation of alkali lignin (48) yielded products with methoxyl content ranging from 10.4 percent to 16.23 percent. Ether-soluble and ether-insoluble fractions differed in composition and properties (49). Alkali lignin when treated with 72 percent sulfuric acid gives about 89 percent acid-insoluble lignin (50).

As yet, no method for isolation of lignin has been found to be free from the possibility of change due to shifts in structure, rearrangements, condensations, or oxidation. Future work, therefore, should center on the study of lignin in wood rather than an isolated lignin.

Biological Decomposition of Compounds Related to Lignin

Researchers have been interested in the possibility of some interconnecting link between lignin and the carbohydrates. Many reactions have resulted in the formation of amorphous lignin-like polymers from carbohydrate conversion products. Wood-rotting fungi was found to grow on lignin as a sole source of carbon (51, 52), but the products that resulted were not determined. When a lignin-destroying bacteria, *Flavobacterium,* grew on alpha conidendrin or vanillic acids as the sole source of carbon (53), a polysaccharide was formed which on hydrolysis yielded d-galactose, d-glucose, d-mannose, d-ribose, and l-rhamnose. Further work in this field may show that there is a biological relationship between lignin formation and carbonhydrate formation.

Lignin-Like Polymers

Many compounds are known to polymerize and form ill-defined, amorphous lignin-like substances. Acid had been found to be a catalyst for polymerization reactions. In a study of a possible biological synthesis of lignin in the spruce tree, Hibbert and coworkers (54) hydrogenated 2- to 3-week-old spruce buds but did not obtain propylcyclohexanol products. A 3½- to 4

month-old tip did yield propylcyclohexanols. Higuchi (55) and coworkers found that guaiacyl, syringyl, and methoxyl groups increased with age in young bamboo shoots. Byerrum and coworkers (56) have shown that methoxyl groups in lignin may result from methylation of a phenol by methionine. These findings indicate that lignin is deposited after the carbohydrate and that methylation is the result of a biological methylation from methionine or some similar agent and not a condensation of some preformed methylated compound.

Klason proposed in 1897 that lignin was formed by the polymerization of coniferin and many investigators have accepted that concept. Polymerization of substituted phenolic compounds to lignin-like amorphous products in the presence of mushroom extract has been known for many years (57). This method of polymerization was studied by Freudenberg and Richtzenhain (58) who found that many substituted phenolic compounds, such as ferulic acid and guaiacylacetone, gave amorphous polymers by the loss of phenolic hydroxyl. Many phenolic lignin-model compounds were found to form amorphous polymers in the presence ot oxygen or peroxide and mushroom extract (59). When coniferin, a product found in wood, was treated with emulsin (to hydrolyze the glucose part of the molecule) and mushroom extract containing dehydrogenase, a polymer (D.H.P.) was formed that was similar to spruce lignin in composition and in its reaction to sulfite (60). Ultraviolet absorption curves were similar (61). Both emulsion and dehydrogenase are found in wood (62).

Sinapyl alcohol does not polymerize readily, but a mixture of coniferyl alcohol and sinapyl alcohol forms a copolymer, high in methoxyl, content at pH 7 (63). The dihydroxy cinnamic alcohol also copolymerizes with coniferyl alcohol, giving a product with low methoxyl content (64).

As a means of identifying the polymerization products, coniferyl alcohol with radioactive carbon in the primary alcohol position in the side chain was polymerized (65). Formaldehyde split from the polymerized molecule by distilling with sulfuric acid had the same radioactivity as the primary alcohol group in coniferyl alcohol, indicating that some of the alcohol group was uncondensed. Isohemipinic acid produced by oxidation of methylated polymer was inactive, indicating the primary alcohol group was not involved in 5-position condensation in the phenyl group. Some meta-hemipinic acid, indicating 6-position condensation, was present in the oxidation products. This product has not been isolated from untreated lignin. Its presence indicated that condensations occur that do take place in lignin production in the plant. This meta-hemipinic acid had 1/3 of the radioactivity of the primary alcohol, indicating some of the primary alcohol groups had been involved in the 6-position carbon-carbon condensation.

Freudenberg placed radioactive coniferin in the cambium of a tree and found it was converted to lignin containing the entire activity (66). Wacek, Hartel, and Maralla (67) repeated these experiments, but were not able to confirm that the coniferin was used in lignification. Wheat seedlings that had been exposed to carbon dioxide containing radioactive carbon 14 synthesized cellulose and lignin containing C^{14} (68). Further work with radioactive carbon should yield a great deal of information about lignin formation.

Much lignin research has been devoted to a search for dimers that would illustrate the mode of linkage between various parts of the lignin molecule. Several dimers of proposed lignin building units have been found in wood and several others have been proposed. Pinoresinol, a lignan occurring in wood extractives, has been proposed as a lignin dimer. Freudenberg and Dietrich (69) found that small amounts of pinoresionl were present in the products when the enzymatic polymerization of coniferyl alcohol was stopped at an intermediate point. When pinoresinol was subjected to mushroom extract, an amorphous polymer was formed that was insoluble in water and soluble in chloroform.

The formation of amorphous polymers from substituted phenolic lignin-model compounds, in the presence ot oxygen and of enzymes present in a tree, may offer a means of studying the synthesis of lignin, if it is demonsarated that lignin is synthesized from preformed monomers and if it can be shown that this method of condensation follows the same path as that followed in the plant.

Chromatography and Electrophoresis of Lignin

One of the problems associated with lignin research has been the lack of a means of purifying lignin or determining its purity. It appears that paper or column chromatography may provide a method for separating lignin into various fractions that may be analyzed by micro methods or compared with other substances by ultraviolet or infrared absorption. Products resulting from various reactions have been separated by chromatography and determined with higher accuracy than had been possible previously. Compounds that had not been recognized previously were separated and identification was made possible.

Bailey (70) subjected various lignins to paper chromatography using several different eluting agents. The lignins separated into several zones, indicating they were a mixture of products. Enslin (71) separated a "native" lignin that had been subjected to several purification treatments into 3 components by chromatography. The fractions were a dark-colored tannin-like product, a yellow fluorescent substance, and a near-white product. Lignin from Eucalyptus *regnans* (72) was resolved into 6 products when eluted by benzene. The product with $R_f = O$ gave the ultra-violet absorption band for lignin. This product was developed by a mixture of methanol, isopropyl ether, and water, and was resolved into 2 fractions with $R_f = 0.05$ and $R_f = 0.95$. Both gave typical ultraviolet absorption for lignin.

Much work must be done to evaluate the products separated in this manner, but it appears that methods are now available for purification of lignin.

Electrophoresis also provides a method for fractionating lignin preparations that are conductors of electricity, such as the lignin-sulfonic acids, and lignin preparations that may be converted to conductors by the addition of a base or salt. "Native" lignins from pine, oak, and maple and an alkali lignin were fractionated by electrophoresis at pH 10.7 (73). The pine "native" lignin appeared to be a mixture of products.

Chromatography has been a valuable tool in the fractionation and identification of chemical products derived from lignin. Bland (74) developed a chromatographic method for the separation of products produced by nitrobenzene oxidation of lignin. Bland, Ho, and Cohen (75) used a chromatographic method to confirm their analytical method and to search for compounds not previously identified. They found all Eucalypt woods yield traces of p-hydroxy benzaldehyde in addition to vanillin and syringaldehyde. Leopold (76) estimated the yields of various nitrobenzene oxidation products from the intensity of corresponding spots on paper chromatrograms and confirmed the presence of several additional compounds in the oxidation mixture. Compounds showing 5-substitution were isolated. The products of several gymnosperm lignins yield 26 to 28 percent total aldehydes based on the lignin and hardwoods yield 40 to 47 percent total aldehydes. The aldehydes from hardwood lignins were about 75 percent syringaldehyde. Chromatographic separation and analysis of products from a low sulfonated lignin from spruce yielded 27 to 31.9 percent vanillin.

Chromatographic separation was used by Pearl and Dickey (77) to separate the products from the oxidation of lignin-sulfonic acids by metal

oxides. Several new products were identified as cleavage products. Products produced by cleavage of lignin by alkali and sodium hydrosulfide showed the presence of methyl cyclopentenolone, aceto-guaiacone 2-methoxy-4-alkyl phenol type compounds, and sulfur-containing products by chromatography (78). Kratzl and Schweers (79) used paper chromatography to separate the monomers formed by ethanolysis of lignin.

Conclusions

The advances made in the past decade in the chemistry of lignin in the field of model compounds and the interpretations they have provided for alkaline cleavage of lignin, the chemistry of sulfonation of lignin, the chemistry of nitrobenzene oxidation, the products formed by biological decomposition, and the changes occurring in the isolation contribute greatly to the solution of lignin chemistry. The information gained in a study of the polymerization of lignin model compounds may aid in developing an interpretation for the formation of lignin in the plant.

The use of chromatography for purification of lignin and separation of products from lignin provide a valuable new tool for lignin research.

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Forest Products Education—A Challenging Problem

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MY TITLE is but a paraphrase of an earlier editorial by W. W. Wellwood, "Forest Products Education, a Report and Challenge", that appeared in this Journal about a year and a half ago. On rereading, it is easy to see that all the problems discussed in it are still with us. Yet, some progress has been made since it was written. One significant event took place on October 28 and 29, 1954, when a small but enthusiastic group of people met, under the auspices of the Education Committee of the Forest Products Research Society, at the U. S. Forest Products Laboratory, to discuss training of technical personnel for the forest products industries. A comprehensive report on this conference will be found on page 33.

Another guest editorial, by C. D. Dosker, proclaims that "Progress is Industry's most Important Product". Who would argue with this statement! The much discussed Stanford report, too, paints a picture of progress in forest products utilization in the next quarter of a century, based on new developments in some areas, but promises at best only *status quo* in other segments of our industry.

Desperately Needed

Mr. Dosker, in his editorial, states that "If an industry is to be successful, it must grow. If it is to grow, it must progress." He also points out that in this age of mechanization and rapid technological development, an industry cannot continue to rely on craftsmen alone, essential as they may be. The forest products industry, to maintain its place among other major industries, needs technically skilled men. One may add, it needs them more than most of the competing industries; it needs them desperately, because it has been, and still is, derelict in promoting the type and quality of research and development that accounts for the success of the competing materials. It needs them because it is also derelict in making use of the information that is already available.

Mr. Dosker tells us that in part, the basic cause of this is to be found in traditional thinking—thinking that is unwilling to use present scientific facts and knowledge. "It is unwillingness to apply imagination to our business," he states. Unquestionably, it is also due to the fact there are too few technically trained men in our industry who are capable of making use of this vast store of accumulated knowledge.

To this, one is tempted to add a third reason—a curious state of apathy, or perhaps the "you do it, George" attitude, that seems to permeate the industry. Why else did a vital discussion of what kind of technically trained personnel the industry needs, and how such personnel could be recruited, draw only a dozen industry representatives? Why, at the association meetings, are the inroads of competition recognized, discussed, and deplored, yet so little done to meet the problem in a way that really matters, by providing funds for research and development, and by encouraging training and employment of properly qualified technical personnel?

Why is it that this vast and complex industry, that has so much to offer to ambitious young men, has done practically nothing about presenting to the youth of this nation its own story? The employment offices of the universities throughout the country are teeming with the representatives of all major industries in search of young talent as insurance of their future; that is, with one notable exception—the forest products industry.

What conclusion is to be drawn? That the forest products industry is not dependent on technological progress for its survival? Or perhaps, that it alone, in sharp contrast with all other industries, can stave off competition with "craftsmen?" We, in the universities, to our amazement and dismay, still hear substantial men of our industry proclaim: "Give me a good high school student, and I don't care whether he ever saw a piece of wood; I'll teach him all he needs to know!"

Industry Indifferent

To be sure, we don't seem to know what kind of college training is the best, or even who should do this training. This was amply demonstrated by the divergent viewpoints expressed at the Madison conference. But, are these not, therefore, compelling reasons why industry should get together with the educators and discuss the problem? Again, one is moved to ask why it is that repeated attempts on the part of a few to bring about such a meeting, have met, if not with actual rebuff, then at least with indifference.

Perhaps the schools that attempt training of technical personnel for the forest products industries are not altogether unselfish in wanting to strengthen and expand their programs of instruction and research. The important point, however, is that they are willing, within the scope of their general educational programs, to meet industry requirements, if only they could find out what they are.

What is being said here has been said before, and much better. It appears, however, that it is time to forego words in favor of action. The only action program that has a chance of succeeding is the one that would bring men from industry, selected by their own groups and empowered to act, together with representatives of the educational institutions, for the purpose of formulating definite answers to the problems discussed at the Industry–Education conference at Madison. This conference acted to establish three permanent sub-committees to deal with: 1) Type of training to be offered, 2) Industry cooperation and 3) Recruiting of students, thereby leaving behind the necessary machinery to make such cooperation between industry and educational institutions possible.

Plan Action Programs

The chairmen of these sub-committees were instructed to invite interested people to membership on their committees. They were further instructed to follow up on the suggestions made at the conference, and to formulate, at a date not later than the FPRS national meeting in Seattle, plans for translating these proposals into purposeful action programs.

The success or failure of this undertaking will depend on the extent of participation by industry. Failure on the part of industrial leaders to assume their rightful share of responsibility in developing acceptable programs of training on the college level would largely nullify the accomplishments of the conference. Of even greater importance would be the effect this failure would have in delaying still further the recruiting of competent technical personnel for the forest products industry. *Can it afford this delay?*

The Industry–Education conference has spelled out the problems that face us in attracting and training technically skilled people. It offered practical solutions for some of them. I urge you to give this report the attention it deserves.

[1] Chairman, FPRS Education Committee.

Industry and education cooperation in developing types of training needed by men entering forest products industry was among discussion topics at conference sponsored by FPRS Education Committee. Left photo shows, left to right: A. J. Panshin, Michigan State College; Gardner Garlick, Protection Products Manufacturing Co.; L. J. Markwardt, Forest Products Laboratory; John Reno, Pacific Lumber Co.; Clarence F. VanEpps, Stromberg–Carlson Co.; Dwight W. Bensend, Iowa State College; James S. Bethel, North Carolina State College; and Harold Sprunger, Dunbar Furniture Company. Photo at right includes, left to right: Messrs. Panshin, Markwardt, Bethel, Reno, and Sprunger.

Industry—Education Conference

A. J. PANSHIN

Chairman, Education Committee, Forest Products Research Society

Representatives of industry and education discuss types of training needed by men entering forest products industry, securing industry cooperation in developing such training programs, and how to interest young men in wood technology and forest products utilization as a career.

AN INDUSTRY-EDUCATION Conference, sponsored by the FPRS Education Committee, was held at the U. S. Forest Products Laboratory, Madison, Wisconsin, on October 28, 29, 1954. It was attended by representatives of industry, trade associations, research organizations and educational institutions offering college-level programs of training in wood technology and forest products utilization.

Objectives

The purpose was to discuss and make recommendations on the following problems:

1. What type of training should be offered men planning a career in the forest products industry, whether it be production, research and development, or distribution of forest products.
2. How to secure the cooperation of the forest products industries in developing such college-level educational programs, and how to stimulate employment of the properly trained technical men by the industry.
3. How to interest qualified young men in wood technology and forest products utilization as a career.

After a brief welcome from Mr. L. J. Markwardt, Assistant Director of the Laboratory, the meeting was opened with a discussion of the objectives of the conference by H. D. Sprunger, Vice President of the Dunbar Furniture Company, speaking for industry. He was followed by Dr. E. G. Locke, Chief, Division of Derived Products, U. S. Forest Products Laboratory, representing the research side, and Dr. F. H. Kaufert, Director, School of Forestry, University of Minnesota, expressing an educator's point of view.

H. D. Sprunger: What does the industry expect of technically trained men? My answer is largely based on my own training, wherein I have benefited and also the weak points. To confirm my own opinions, I wrote five University of Michigan graduates whom I knew to determine where our training had been of the most value, as well as the pitfalls.

A technically trained man should have a thorough understanding of the fundamental aspects of wood as the prime raw material of our industry, the know–how as to conversion of primary and secondary products, and the ability to analyze problems and apply technical information to their successful solution. Finally, he must speak and write well, and have some training in the social sciences, communication skills, personnel relations and business administration.

Let us take a closer look at these main categories. For a better understanding of what wood is and how it becomes available, he should have been exposed to a general forestry course in management and forest economics, and know structure, identification, mechanical and physical properties of wood. It is also to his advantage to have been exposed to a survey course in wood

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chemistry and to have a working knowledge of converting wood to its primary and secondary products. To do this he must know the fundamentals of machine woodworking, familiarizing himself with the operation of all the basic woodworking machines, their capabilities and limitations. His training should include understanding of the principles of woodworking machine design. He should know the methods used, cost and quality control of production of lumber and dimension stock. He should be familiar with the principles and application of the grading rules. It is also well that he have some knowledge of the marketing of lumber and allied wood products. He must know the correct method of lumber seasoning, the principles of kiln drying and the advantages and disadvantages of various types of kilns and drying schedules. A working knowledge of protecting wood from destruction, deterioration by decay, fire and insects is also valuable. He should know the sources, characteristics, properties and testing methods of various adhesives used in glued-up construction, as well as be familiar with the proper preparation, assembling, bonding, conditioning, physical properties and utilization of plywood. He must be familiar with the preparation of wood for finishing and should know the chemical and physical characteristics of varnishes, lacquers, resins and other finishing materials. He should know various methods of finishing application and be able to evaluate their effectiveness.

Knowledge of factory management principles, plant layout techniques, time and motion study, statistics and their application to quality control are necessary qualities in the trained man. He should be familiar with other engineering materials and their uses, such as various types of alloyed steels, nonferrous metals, glass and plastics. I think it is understood that the prerequisites to many of these technical courses would be general chemistry, physics, engineering, drawing, mathematics and English composition.

Production Asset

Thus educated, we have a technically trained man who, with a good proportion of common sense, could go into a wood-using plant and be an asset for production. However, because most firms in industry are rather small, he still needs some training in other fields to give him a better insight into the problems of management. He should possess some knowledge of general and cost accounting, business practices, business law, economics, psychology, and labor relations, and should have been exposed to good literature. I would say that the technical courses and their prerequisites should comprise about two-thirds of his formal education.

We all realize that technical training is what gives us the tools we need in the operation and development of our businesses; however training in the art of communications, social sciences and business administration enables us to sharpen these tools to do even a better job. How this training was presented to the student and his reception to it will show up in the attitudes that he has developed. Has our technically trained man been taught in such a way as to stimulate creative thinking? Can he analyze some of the problems that our business faces and apply his training to their successful solution?

One thing that was noticeably lacking in my own training was experience while learning. A responsibility of our universities and our industry is to work out a solution that will enable the student to gain actual plant and factory experience. I heartily recommend a year of it while he is working for his degree. I know that this may be impossible because of limitations now prevalent in working on a four-year course for a Bachelor of Science degree. At any rate, we must insist that the technically trained person be required not only to take the technical courses pertaining to his field but also those that will train him in communication skills, social sciences, business administration, personnel relations. Above all he should be exposed to some of the courses that deal with the fine arts. A person so trained not only becomes an aid to production but has the ability to become a future executive of our industry.

Edward G. Locke: In considering the personnel requirements for research and development in the forest products industries, we should review the way these industries have grown and developed. Only since World War II days, let's say 1945, has research and development played much of a part in the forest products industries, with the exception, of course, of the pulp and paper industry. I think that is true because these industries are made up of so many small, diversified units.

The war stimulated research and development, not only directly, but by exposing many of the men in the Armed Services to the results of research and development. After the war, colleges and universities were besieged by representatives of industry seeking men to staff their organizations, including their newly organized research departments. In many cases these representatives of industry did not know what training their men should have. They merely wanted men. As a result, the job of the educational institutions has been a difficult one.

I believe the demand has been for what I choose to call "vocationally" trained men, not men trained in the basic sciences and engineering. Industry has wanted men who could go out into the factory and take their places immediately in manufacturing operations. Many of the men in industry forget that a college or university trained man usually has little or no practical experience, and that he comes to the plant mainly with background information, well prepared for the specific education that the company must furnish him. As a result of this demand by industry, the forestry schools have become more and more vocationally-minded. It has become difficult for research and development groups to find men at the forestry schools with satisfactory training in fundamentals.

Two Phases

In research we are interested in men who can apply fundamental scientific principles to wood in any of its forms —as a structural material, a chemical raw material, or some intermediate form. To do research we must have men who are trained in the fundamentals, and who know the basic sciences. The same is true of men engaged in development work in the forest products industries. In improving an old product or producing a new one, there are two phases: First, it is necessary to examine the basic principles of the problem; then the results of the basic investigation must be expanded to produce a practical solution. We should not have to rely upon the trial and error method so often used for research and development work. We should be able to follow an orderly scientific process, whether the problem is one in pulp and paper, plywood, in the construction industry, or the manufacture of charcoal.

Fundamental Training

Unfortunately, in charcoal manufacture we have had no real fundamental work since about 1900. If the wood distillation industry is to expand, that expansion must be based upon a study of the kinetics and thermodynamics of the distillation process, not upon trial and error. What kind of a man does that call for? It calls for a man trained in fundamentals. It calls for a chemist or a physicist or an engineer. In other types of forest products research we might want botanists, plant physiologists, mathematicians, or mechanical, civil, and chemical engineers. These are the men we need in research and development—not men trained vocationally.

Some of my friends in the teaching profession have told me that this "basic training" idea is fine, but that industry

wants men that are vocationally trained. I sometimes wonder, does this industry know what it wants? I think the forest products industries would be much more advanced if more of the men in plant operations had basic training upon which to superimpose "vocational" training by the employer. I believe it is up to the college and university professors to sell the industry on the benefits of hiring men with such training. I will not attempt to outline a course that I would consider adequate, because the staff members of our educational institutions are better qualified to do that. However, I do feel that if we are to progress and to improve our methods of processing wood, we need men trained in the basic sciences.

Men engaged in research and development work in the forest products industries must know all they can about wood, that is true. But a chemist, physicist, mathematician, botanist, or engineer can readily be trained on the job. Naturally, survey courses in forestry and forest products would be a help to any graduate, but not if they are taken at the expense of fundamental training.

Retraining Necessary

I talked to many personnel men during my previous experience as a college professor. They told me that men who have too much applied training must be retrained on the job, often with considerable difficulty, in the ways the company is operated. Now I don't want to belittle vocational courses or vocational training, but I believe that a man trained in fundamentals can get his vocational training in short courses or in-service training programs.

You may say it is difficult to get a research and development organization started using men who know little or nothing about wood. But there are plenty of men now in research organizations who do know something about wood and who can supervise the work of technically trained men and train them so that they have the information they need about wood.

There is one field of training that I have overlooked—wood anatomy. A wood anatomist is trained in fundamentals, and might, according to my classification, be called a true wood technologist. Such a man can contribute much and is a necessary part of a team made up of scientifically trained men.

Writing Is Essential

One phase of the training of a research and development man cannot be overemphasized; that is, training in report writing. Often it is only through a written technical report that a research man can reach a busy president or vice president. These men will not spend more than 2 or 3 minutes on a report unless they are immediately impressed with the importance of the story. Since research men must get their story across to high-level management, report writing is an essential part of their training.

Men in research and development work must also be able to get along with their fellow workers, so some of the students' electives should be in the social sciences, such as sociology, economics, and psychology. These courses will help them to understand their fellow men.

Let us look for a moment at our forest products industries (including pulp and paper) as they are today. I can count on my fingers the true research and development departments in these industries. Many companies have what they call research and development departments. But have they? I have heard how some of these research and development departments were set up. They picked out a bright young man with some college training, put him in a small room, and wrote "Research Laboratory" on the door. In the room they placed a bench, possibly a small press, and a few tools. Then they said, "You are our research department. Let's see what you can produce."

To me that type of research setup doesn't make much sense. A research and development department must be well conceived, well planned, and well staffed with properly trained men. A good research and development department can pay its own way—it must. But it is men trained in the basic sciences who will make it pay. The formal education of these men is only the beginning: their training in the basic sciences is a foundation upon which to build. If they are to be successful in research and development work, their study and training must never stop.

Frank H. Kaufert: The question of what type of training should be offered men planning professional careers in the forest products industry is not greatly different from that faced in training individuals for fields such as forest management, engineering, and agricultural specializations. The problem is one of obtaining a reasonable balance between general training of the individual, the type of training that distinguishes professional from strictly vocational training, and the subject matter courses that introduce students to the numerous forest products techniques, processes, etc. Training programs that are largely vocational in nature have limited place in universities and colleges. I say that because we have among our graduates generally fewer reports of failures because of lack of knowledge of subject matter material than failures resulting from lack of ability to speak, to write and to work with people generally.

Four-year professional training programs in universities and colleges should contain at least two years of basic background work in such courses as English, mathematics, chemistry, biology and similar courses. I won't name all of them and they may and do vary from one instiution to another. The social sciences, sociology, economics, history, and other courses should be included and occupy at least another half year or possibly a year. Public speaking and writing are other important components of a professional training program. At the most this means a year and a half to devote to subject matter courses in wood technology, business, merchandising, etc.

In this year or year and a half, the students can be given an introduction to the entire forest products field through survey courses and more intensive coverage can be given a few subjects. It seems to me that in 4-year professional training courses the only compromise possible is in the last year or so of the program. If the student has made a selection of fields or has established objectives by the time he has reached his last year or so of training, he can specialize with little or no loss or weakening in his training program. If he is not ready or willing to specialize at this point in his training, he usually will complete his four-year program with a sound general background but with relatively little specific training for individual jobs. To attempt much more than this in a professional training program appears to me to be unrealistic.

Develop the Individual

The emphasis in the four-year professional training program must be on developing the individual. If we can accomplish this and provide him with a sound background of basic knowledge and understanding, most individuals will be able to rapidly and effectively master the complexity of processes and products when they enter industrial employment. Individuals with such training may not be able to operate machines or do the numerous other jobs that require a knowledge of processes and equipment and products. Such skills are usually developed only through long experience, but these individuals should have the background to better understand and quickly grasp the details and complexities involved. I am not particularly concerned or disturbed by the variety and number of subject matter courses offered in wood technology or utilization curricula, nor am I concerned too greatly by the variety of names they carry. Usually, only a limited number can be included in professional programs limited to four years.

It is not the purpose of professional training to develop machine operators or skilled workers, and it is a mistake to attempt to achieve this objective in addition to providing professional training in any program. An accumulation of factual material is important, but it is not the primary objective of professional training. Educators and prospective industry employers must recognize this if professional training for the forest products industry is to achieve its objective. Again, I have less concern with the name of the program than with its soundness.

Experience is important and every effort should be made to get students to take summer jobs or part time jobs where they will have contact with operations and get practical experience. The importance of summer jobs and part time jobs cannot be overemphasized.

Graduate Work Essential

There is relatively little opportunity to train for research in the forest products industry during four-year professional programs. This can be accomplished effectively in training at the Master's or Doctor's level. There is room for all type of training, it seems to me, in the forest products research field. As Dr. Locke has pointed out, that is exactly what you find. Certainly there is room for chemical engineers, mechanical engineers and all types of engineering training. To produce effective research personnel, training at the graduate level is essential. This is just as important for engineers as for forest products technologists.

In addressing myself to the second point, ways and means of selling the forest products industries on the need for technically trained men, in my opinion there is no single or simple method of accomplishing this important objective. There is need for recognition on the part of industry that continuous development and improvement in products, processes and distribution are essential for successful competition. Skills and knowledge beyond those now available are needed to accomplish this. Meetings of this type and the work of such groups as the Forest Products Research Society and a closer contact with industries and schools is also important. However, it seems to me that the most important and finally the real selling point are the success and accomplishment of our product, the young men we train. As they take their place in industry, are accepted and achieve success, so will the programs in which they have been trained, whether wood technology, utilization, merchandising, packaging and others, be accepted and achieve success.

In connection with the last point, ways and means of interesting qualified young men in such professional training programs, I think the schools have a big job to do. Some of them are doing a good job now. Others are starting to put out the type of material which tells what wood technology and other forest products training programs are and provide information on job opportunities. The work of successful alumni seems to me to be a second factor. As more graduates of these training programs find themselves in positions where they can employ individuals with similar training, if they have confidence in the programs in which they were trained, we will obtain greater acceptance of these programs and will have more individuals entering. The industry obligation in connection with interesting young men in these programs is a major one. The chemical industries and the industries using engineers advertise the opportunities available in those industries for young men. You see very little, if any, of this in the field of forest products. I have wondered why representatives of our industries, with the confidence in the future which I feel many of them have, and all should have, don't do more to advertise the opportunities for young men in the forest products industries. Such advertising and information would result in the entrance of a greater number into training for this field, whether that training be through engineering, forestry, or other schools.

Discussion

Hardy L. Shirley. In any meeting of this sort, where educators, men of industry and others get together to talk about what they'd like to have, they invariably bring into the picture early in the game the poor quality of the students and in particular the poor training they have in the high schools and grade schools. But I don't know that they really have been quite fair in that. At least, my experience is that students generally as they come to us now are as well prepared for college as I was when I went to college and a great deal better, most of them. The major difference that I can see between the students of my day and the students today is that those today are a bit more serious-minded.

It is the job of the educator to stretch their minds and potentials, and to give them as diverse experience as we can so that they are not one-sided individuals. Then, it is our still greater job to make them permanent learners, so that they learn throughout the rest of their lives. If they have learned how to become good learners while they are in college, I feel that the educator has just about done his share and that it is the job of the graduate school and on-the-job training to do the rest.

John Reno (Pacific Lumber Company): I approach this problem from the standpoint of a practical lumberman. If a man enrolling in a course which is slanted toward the forest products industry knows definitely at the time of his enrollment just what branch of industry he plans to enter—production, research or distribution—his curriculum could be adjusted to emphasize the training he would need to prepare him best for his chosen plans. However, what percentage of students have decided prior to their entry in just what direction they wish to head? If the percentage is small, the first two or three years should be a well-rounded curriculum such as some schools now offer, with the fourth year devoted to the branch he has finally chosen. As a matter of fact, I'm not sure but what this latter arrangement would not be better in any case.

I am of the firm belief that the research man should be well grounded in forest practices, lumber production and distribution. He should be a fluent speaker and a good salesman so that he can sell his programs to his fellow worker and to the man who is going to pay for them. Likewise the production man—and I mean the man in the sawmill or in the plant—should have some knowledge of forestry, research and distribution. He should be a good wood technologist and able to speak well. Certainly the salesman should be well informed on forestry practices, production and research. He should be a first-class wood technologist and a good public speaker. He should know wood utilization better than the utilizer. He should know more about correct building practices than do the builders. He should be the authority to whom his customers could turn in confidence for complete guidance.

I think our main job is to convince industry that our graduates have training that will prove valuable to industry and that they will prove better assets at the higher salaries they want than are the untrained applicants, be it in production, research or distribution. In contrast, we must convince our graduates that they still have a lot to learn after leaving school, that they are not in a position to demand the world with a fence around it but must sell themselves to a reluctant industry, especially in the production and distribution end.

Trained to Meet Competition

How to interest qualified young men in wood technology and forest products utilization as a career? One way to do this is to keep a perpetual list of successful graduates, showing their affiliations and successes. Probably we should cir-

cularize mailing lists to high school students enrolled in woodworking; also lists of schools offering technical training in the forest products field to industry, the retailers, the commission salesmen, the wholesalers, the producers. These should be invited to enroll their sons and others in courses on the premise that they will be trained to carry on the business in a manner to meet modern competition.

Now I'd like to talk just a little bit about what Dr. Locke had to say. I think that when he asked for the chemist and the physicist, the men who are trained in those lines without any lumber or wood technology training, he really meant that they should have at least a year or two of wood technology. I think any man coming into the U. S. Forest Products Laboratory without knowing something about lumber and wood technology, is handicapped. He's a specialist, yes, but personally I think he will go farther if he knows more about the material with which he is working. Again, he didn't mention too much about applied research; I think he had in mind fundamental research such as we have at the Laboratory. I believe that what I have to say about the research men applies with even more force to those who figure in applied research for the various lumber companies. I personally am of the belief that every retail lumber yard of any size ought to have a man trained along the lines discussed here. They should have a man who knows all about lumber, and if you think there is no room for high-salaried men like that in the retail lumber business, I think we're taking a negative attitude. I am convinced that such a man would pay his way because I'm thoroughly convinced from my own experience in the lumber business that a man like that would be invaluable.

Dr. Kaufert talked about background training. I don't think for any of our four or six-year college men it is necessary to learn how to set up a molder or a sticker. I think they have a hard time learning to do it anyway. But they should know the function of every woodworking machine. I didn't learn that in college. I went to night school for about nine years to learn enough about stickers and molders and all the other woodworking machines so that I could help my customers when they get into trouble.

Intelligent Utilization

L. J. Fitzpatrick (J. J. Fitzpatrick Lumber Company): I am representing Sid Darling who is Secretary of the National Wholesale Lumber Association, New York. I would just like to say that I think that what we're talking about can be lumped into one title, "The intelligent utilization of forest products." This includes production, sales and consumption. Actually by profession I am a lawyer, and I have three other lawyers in my company. My job is to read; and I find that through a rapid reading course I have improved my reading time from 450 words to 570 per minute, in two lessons. The faster we can read, the more we can assimilate. Public speaking is tremendously important and so is English. Accounting, also is vital in any field because after all what we are trying to do is not just to get a man who will be solely a research man. We have a man in our organization who graduated from the University of Minnesota Forestry School and then took a job in accounting. We weren't big enough to have just an accountant or just a kiln expert so we found in this man the perfect combination and it's worked beautifully in our case.

I think we have one of the most excellent means of telling the story to the manufacturer, the retailer and the wholesaler — the Forest Products Research Society. Also the new tax law that was passed recently is important to us in the manufacturing field and in the wholesale field. It has a very nice clause in there which will permit a company like mine to set up a research department and deduct it over the next two or three years.

Industry Representation Needed

Now I think the last item, ways and means of interesting qualified young men, is by far the most important. In the National Wholesale Lumber Association, we have formed what we call the National Association of Wholesalers to get the story over to the students throughout the country on what is a wholesaler. At Ohio State University we set up a course in wholesaling where we sponsor boys every summer for this course. One more comment and I'm through. John Reno mentioned that I was the only wholesaler here, and I'm here by sufferance because Sid Darling couldn't be here. I think he is absolutely right, and I think we should have more manufacturers represented at a meeting like this.

Thomas H. Cook (National Casein Company): I think we're asking too many things to be done in school which can be learned outside and which can be learned better. For instance, public speaking. Why should they bother teaching it in school when if a man is interested, he can find a way to do it outside, for instance, join a civic club, become active in a church, etc. We want a perfect man but why does he have to learn it all in school?

E. R. Martell (Department of Forestry, Purdue University): A gentleman in the back of the room said a moment ago that he thought the problem how to attract students was most important of these three items. It seems to me that this is the easiest one to accomplish. If the inducement is there, either from the standpoint of interest or financial return, you will interest these young people. Is the interest there? Dr. Panshin said that more than 100 invitations had gone to industry, and industry is certainly not represented in any large number here this morning. To me that's indicative of questionable interest.

We talk about retailing, but with the exception of a few chains of retail lumber outlets, most of these lumber outlets are small, family-owned. A young man who is trained in this particular field gets a job at beginning salary out in the yard, but the promise of the future that he has open to him in this particular type of employment is relatively small because of what typically happens. Along comes the son, the nephew, the son-in-law, and takes over the better position. I don't see how, if I were a student, I would be particularly interested in going into something in which the future is relatively limited.

We have a summer employment committee in the Council of Executives of Forestry Schools that has been attempting to work with industry from the standpoint of summer employment. We recognize that our technique has been faulty and that there are other features in the picture besides the one I will describe to you. This procedure, which we have been trying to work through the National Lumber Manufacturers' Association and its regional offices for the past two years, has resulted in not one single temporary summer job for a forestry student from any of the forestry schools to the best of my knowledge, and I know of 20 to 25 accredited schools. Why? Well, outside of these mechanical difficulties we have run into, again this question is raised in my mind—interest.

Toughest Kind of Competition

If you have looked over the Stanford Report, which is now available, those of you in industry and we in the schools are faced with the toughest kind of competition. If industry is not now on its toes from the standpoint of research and development, or of employing skilled people, I see little future for it. A view that is held by a relatively large number of people, is that with the exception of a conspicuous few large, stockholder-owned companies, we are dealing with relatively small, closely held industries; and, as Dr. Locke

pointed out a moment ago, when it's raining, that's the time to do your research. Typically speaking in the wood-using industries, either primary or secondary, we are like the man with the leaky roof. When it rains, you can't get out and fix it; and when times are good, why should you fix it?

C. F. Van Epps (Stromberg–Carlson Company): I wonder if we couldn't take just a couple minutes here and define this man we're talking about. It seems to me that the terminology "wood technologist" is hardly a reward for four years of the kind of work you put these fellows through; hardly descriptive, either, for people in industry. For example, we hear these young men described as Bachelors of Science in Wood Technology or Wood Utilization, or something of this nature, yet the emphasis has been on the idea of an engineering background. As a suggestion, what is wrong with the terminology "Wood Engineer"?

F. F. Wangaard (Yale School of Forestry): There are a number of educational institutions represented here this morning. How many engineering schools are represented?

C. F. Van Epps: I do think that the terminology "engineer" means more to Mr. average-person-on-the-street than a B. S. in Wood Utilization, for example. The terminology "technologist" in the engineering field means somebody that generally works in the back room. I think it belittling just a bit to your graduates, and I think it could stand some serious improvement.

Michigan Problem

F. E. Dickinson (Department of Wood Technology, University of Michigan): You may have attended the FPRS Education meetings at Memphis and in Grand Rapids, where that point was brought up. As a result of these meetings, and to bring myself up-to-date on the situation at the University of Michigan I discussed this question with our Dean of the School of Engineering and also with Dean Dana, then the Dean of the School of Natural Resources. At the time when the School of Natural Resources was divided into its five existing departments, of which Wood Technology is one, Dean Dana conferred with the Engineering School, and said, "here is an area which is more engineering than it is forestry, would you like to have it?" The Engineering School said, "No, we do not want it, nor do we want the name of "engineers" tacked onto your men." Since that time there has been a new Dean of the School of Engineering so I again investigated the situation. Their answer was again, "we are not interested in this field but we are interested to the point that we do not want your graduates called engineers."

And while you may think that the term "wood technology" has connotations, let me point out that the term "engineer" also has connotations. For example, in Lansing there is an accrediting bureau for engineers in the State of Michigan. We have boiler engineers, we have house inspection engineers. Most of those categories take men at least with a high school education and a certain amount of experience in the trade. I only offer that as a very definite problem we in Michigan have, recognizing the truthfulness of the point you are making.

F. J. Hanrahan (The American Institute of Timber Construction): I am a structural engineer; I also believe the foresters have a reputation to live down. I'm not saying that disparagingly, but back about 25 years ago about the only training that a forester got was for government service. There was very little training for utilization.

Emphasis on Fundamentals

Industry by and large likes to think in terms of utilization. These foresters were thinking in terms of silviculture. They had to be totally reoriented with respect to the industry viewpoint before they became of much value to industry. Also, most of them lacked training in fundamentals other than silviculture or forestry that could be used to good advantage for other purposes. I might point out that in engineering emphasis is on fundamentals and on the basic sciences.

I am not saying that engineering is the only type of training, but I do think one thing might be done—let the fundamentals be obtained from various schools, and then let the orientation courses in forest utilization be added to indoctrinate the student so he can apply these fundamentals in the particular field in which he wishes to specialize.

Ernest Wohletz (School of Forestry, University of Idaho): I want to back up the statement that it is difficult in colleges to call anything engineering unless it is in engineering. At Idaho we have recently asked that the Mechanical Engineering Department take over our so-called "chemical phase" of wood utilization. They hesitated very definitely in so doing, the reason being, the engineers are probably the most highly organized group in the world from the standpoint of accrediting. Consequently, in order to get the engineering phase in at all, we had to call wood utilization the mechanical phase. It is a difficult term, but as close as we could come because we couldn't call it even wood utilization engineering phase.

Years ago we were able, before accrediting became very strong, to put in what we called "agricultural engineering". You will find it in most colleges now as agricultural engineering. But I don't think today we will get in Wood Engineering or similar phrase because the accrediting associations are watching it very closely. One solution, possibly, is on a longer than four-year term. Combining wood and engineering phases would require more than four years. In the case of the engineering curriculum examination shows that if a student desires, say, some wood technology or wood physics or other courses taught in forestry, he cannot get them in the engineering curriculum because it is already filled up. And to remove an engineering course in order to put something else in, our accrediting system will not permit.

Joseph L. Muller (National Hardwood Lumber Association): We want to keep sight of our objective and not presume that we can build some kind of mechanical brain in the course of a college education which, when turned loose, is going to resolve all of the problems of industry and science. To say that a student should know more than anyone in industry knows about its products is impractical. It certainly would simplify our responsibilities to conveniently turn them over to this new mechanical brain. No, I believe that we've got to be thinking in terms not only of the proper utilization of the product, but proper utilization of the student as well.

We have to keep in mind that we are dealing with young men. Under today's society these young men have gone through eight years of grade school training, four years of high school and probably right directly into college. The majority, except for the veterans etc. have, since the day they were taken to kindergarten been under a very carefully patterned educational program, with little or no outside practical experience.

Both Sides at Fault

Colleges are expected to give students fundamental know-how; industry must continue to train them on the job. When a young man comes from college, he has given evidence that he is interested in this field of work, and that he has the average intelligence to make the grade. At that point industry has got to extend a welcoming hand and further develop him into a specialized technical man. Perhaps our industry and universities are at fault in failing to appreciate the value of such men, in the tendency to over-evaluate them, and in failing to utilize more of these men. Our universities are also at fault in failing to bring to the attention of industry what they have to sell, *young men*. There must be a greater

public information service on their part directed toward selling their product. If they do that, we will have a greater interest on the part of industry in these men, and a greater interest on the part of the young men in taking such training.

Gordon D. Marckworth (College of Forestry, University of Washington): Going back to what Mr. Van Epps said, I think we do need some sort of a label on these graduates. It has been our experience that when they go in to talk to somebody, the personnel manager or head of a company about a job, and they say they have had training in wood technology or forest products, they want to know well, what's that? Then they have to explain what their training has been. When an engineer goes in, he says he's a chemical engineer and at least they think they know what a chemical engineer is. They've heard the term before.

About using the term engineer, we have in our college a special curriculum in logging engineering. It's been there for a good many years and our graduates can take the examination when they get through and become a licensed engineer in the State of Washington. But we don't believe that the term engineer applies exactly to our graduates. Frankly, we don't know what to call them. If we could get some name which would be accepted by the people in industry and elsewhere, I think it would be a very fine thing.

George B. Hartman (Department of Forestry, Iowa State College): I was interested in the comments which Mr. Muller made because they emphasize the problems that the folks in the schools have had for many years of trying to train men that will be acceptable to all segments of the industry. And that's one big job. If you don't believe it, just try it sometime. That's why all the schools have the problems in working up various curricula that they have. I thought you might be interested in just a few figures. They pertain only to our own school, but I have an idea that the other schools probably have about the same experience. Every couple of years I try to evaluate our graduates as to what they are doing and as of last August, 37% of our graduates were engaged in private industry as against 33% in public service of all kinds. Of this 37% in private industry, over two-thirds are in production, by which I mean the manufacture of forest products or plywood or some wood industry. Eight per cent, in sales and distribution, have come out of what up to now has been a very general sort of a curriculum. We do have a wood utilization option in the school now; however, these men have been trained in the general curriculum. We have a few in research although I think most of them would fall in that group which should more properly be called development. I think it is significant that this general training has produced men that have gone into this type of work, and I think it emphasizes what Mr. Muller brought out, i.e., that college training cannot be too specific.

Reports and Recommendations of Sub-Committees

Following general discussion of the objectives of the conference the members were divided into three groups, each charged with the task of preparing definite recommendations for each objective. The entire group reconvened the following morning to hear and to discuss reports of each group.

Group I Report, presented by C. F. Van Epps, Chairman: The assignment given to this group was to make recommendations concerning the types of training to be offered to men planning a professional career in the forest products industries, whether it be in production, research and development, or distribution of forest products.

In view of the wide diversity of the forest products field, as indicated at the morning session as well as in the subcommittees, it is apparent that a detailed final recommendation can be developed only after much additional study of the problem. The committee was in agreement that at this stage only the broad outline of a curriculum (or curricula) can be drawn.

The importance of a broad base of fundamental courses in the social sciences, physical sciences, mathematics, and English was stressed. Only upon such a basis can a strong professional program be built. Some feeling was expressed, however, that professional courses might be introduced fairly early in the 4-year program as a means of stimulating the student's interest in his chosen profession.

The objective of a professional curriculum should be primarily to develop the students' abilities to think clearly and to analyze problems of the type which will confront him after graduation. He is not to be thought of as a finished product upon completing his college education, and his education cannot be considered successful unless it has provided him with a capacity for further development as he gains experience in industry.

The committee recognizes that a professional curriculum in the field of forest products may be developed by considering courses within the following broad areas of instruction:

1. Courses taken by all students (general education).
2. Courses taken by all forestry students.
3. Courses taken by all forest products students.
4. Courses taken by students with major interest in
   (a) Products of primary manufacture (1) Production (2) Distribution.
   (b) Products of secondary manufacture (1) Production (2) Distribution.
   (c) Research and development
5. Elective courses selected to meet individual needs.

A committee on the Evaluation of Engineering Education[1] has suggested the following time distribution among the several areas within a professional engineering curriculum:

	Semester Hours	*Percent*
1. Humanistic–Social	21	15+
2. Mathematics and Basic science (about equal)	36	26+
3. Engineering Science	36	26+
4. Required Technology	7	5+
5. Major departmental sequence of Engineering Analysis, Design, and Engineering systems	21	15+
6. Options or Electives in a) Humanistic–social b) Management c) Basic Science d) Engineering Science e) Research or Thesis f) Engineering Analysis or Design g) Technology.	17	12+
Total	138	100

A close parallel between these broad programs in forest products and engineering is apparent. Although recognizing the fact that the pattern of five broad areas of instruction outlined above fails to cover certain fields demanding specialized training (for example, pulp and paper manufacture), the committee feels that it is sufficiently broad to meet the needs of the majority of forest products industries.

Further Study Recommended

Consequently, it is our recommendation that a committee representing education and industry be established to give further study to this matter. It is our feeling that within the broad outline submitted here, and giving consideration to the analogous program that has been suggested in the field of engineering, a balanced program of basic and technical training can be developed for the major areas of specialization in the forest products field.

Specifically, we recommend that the committee appointed for such a study should include in its assignment a comparison of the curricula so developed with those currently being offered by the various schools. The attached summary of existing course programs is submitted as an aid to the new com-

[1] Journal of Engineering Education, Vol. 45, No. 1, pp. 40-66, September 1954.

mittee.[2] The committee also recommends that wherever possible forestry schools encourage students in engineering schools to take advantage of elective courses in wood technology and utilization.

Finally, it is suggested that the expressed desire of industry for strictly vocational-type training be met through short courses, clinics, etc. designed especially for that purpose and consequently minimizing the need for this type of instruction in the professional college curriculum.

Group II Report, presented by John Reno, Acting Chairman: The assignment to this group was to make recommendations on how to secure the cooperation of the forest products industries in developing college-level educational programs, and how to stimulate employment of the properly trained men by the industry.

The group recommends that a permanent sub-committee be set up to stimulate the education of industry on the value of technically trained men. Pertinent information could be channelled through the National Lumber Manufacturers Association, regional manufacturers' associations, state retail lumber dealers associations, all other special associations, AFPI, Forest Products Research Society, and its Sections, company publications, as well as the various associations of the wood by-products manufacturers, pulp and paper associations and others. Of paramount importance would be the trade press.

Individual schools should be encouraged to circularize industry in their areas, and prepare articles for the Journal of the Forest Products Research Society and the trade press generally, describing the types and fields of training offered, including facilities, curricula and research programs.

The organization of sessions on this subject at national and sectional association and society meetings was also recommended. These could include symposia on the contributions of technically-trained men. Industry principals should be induced to visit colleges and meet faculty members and students, thus becoming more familiar with what the schools have to offer. Similarly, students and faculties should be invited to their operations, and to attend and participate in technical and other types of meetings sponsored by industry. Industry should consider the possibility of inviting student speakers to their meetings and conventions.

Group III Report, presented by F. E. Dickinson, Chairman: This group considered ways and means of interesting qualified young men in wood technology and forest products utilization as a career.

In considering the above subject, the members came to the conclusion that a program aimed at accomplishing the desired objective of interesting qualified young men in wood technology and forest products utilization as a career is justifiably sponsored by FPRS, not only because of the great benefits that will accrue through dissemination of technical knowledge in the industry, but also because the young men brought into the industry through such a program will potentially make excellent membership material for the Society.

The problems are, first, to interest students on the high school and college level to inquire about possibilities, and, secondly, to get the proper information into the hands of advisers on the high school level. Competition with other fields, particularly engineering, is keen, and salaries and job opportunities available to properly trained men are often determining factors. Even the offering of scholarships on the undergraduate level is not a great help—witness the experience in the pulp and paper training field—if applicants for such scholarships are not forthcoming.

The time is ripe for a program of broad, nation-wide dissemination of information on the importance of the industry in the economy of the country, on probable future trends (as based on the best current information available, for example, in the Weyerhaeuser-Stanford report), and on possible current and future job opportunities and salaries. The fact that many wood using firms are small, closely knit organizations should be pointed out as an advantage, for it offers the opportunity for many individuals to rise to positions of owners and managers of their own businesses. Following are the recommendations of the group.

1. Because the American Forest Products Industries has a considerable budget available for dissemination of information about wood industries and because it has established channels of distribution to educational institutions, particularly on the high school level, this organization should be approached regarding the problem of interesting more individuals in considering a professional career in the forest products industries. The assistance of FPRS should be offered in the preparation of a brochure that will point out the importance of the forest products industries, in the economy of the nation, the opportunities for employment, in a general way, in the industry, and the qualifications required for such employment. Any other organizations of manufacturers, wholesalers, and retailers, that may not be associated with AFPI, should also be contacted.

2. FPRS on its part should publish more specific information for limited distribution to members and for answering inquiries that may develop as a result of the more general AFPI brochure. A small leaflet (perhaps only a single page) is proposed, listing schools offering specialized training in forest products and giving information about opportunities, about accomplishments of graduates, and examples of salary ranges.

3. The FPRS leaflet, as well as any other FPRS publications which may be developed bearing upon this subject, that would have the purpose of directing interest to the forest products industries as a field of employment, should also be made available in quantity to industry firms that will be willing to distribute it, at their own cost, to their mailing lists.

4. The forestry schools should be encouraged to continue distribution of their own brochures on the local level.

5. The members of the group recognize the tremendous potentialities of using advertising opportunities that may be made available through private advertising of public spirited firms in this field, in national and trade magazines, on radio and TV, in film strips, movies, and the like. FPRS should be aware of every such opportunity. The time was too limited to explore these possibilities fully.

6. A recommendation is made to the education committee that an annual record be made of curricula and degrees granted in courses related to forest products, for publication in the Journal.

7. The group recognizes that the objectives of the program outlined here cannot be attained in a short time. It is therefore recommended that this program be made a continuing one in the Forest Products Research Society.

Discussion

F. E. Dickinson: I think it is a very fine idea to have students invited to address industry meetings, but how do you accomplish it?

John Reno: You just do it. We could start with ourselves. It is very easy to accomplish that in the Forest Products Research Society and I don't think it would be any job at all to get forward-looking executive vice presidents of the National Retail Lumber Dealers associations or secretaries to go along with this idea.

J. L. Muller: I don't want to think that the colleges have been at fault in failing themselves to keep contact with the industry—in reading their journals, etc., attending some of their conventions as faculty members. I say that in reference to this actual experience. For

[2] See "College-Level Education Program for the Forest Products Industries", by F. F. Wangaard, pp. 42–44.

two years we tried to develop an interest along this line through our junior conference group who ran an essay contest on the question of hardwood lumber, for which there were three prizes—the first one to include a trip to the convention and to have an opportunity to present that paper before the convention body. We got three papers and there were 3 prizes so they got first, second and third prizes. We tried it again the following year and got absolutely no response or interest. This was publicized in forestry colleges and newspapers and nothing happened. So there has got to be an interest on both sides.

I say it can be done by maintaining closer personal contact and interest both ways in what each other is doing and I'm sure our association as well as many others will be most happy to have any of the faculty members attend the conventions scheduled for the association.

G. D. Marckworth: I don't think the essay contest can be put over. It has been tried by various associations all over the country and it's been a failure wherever you have it. In Western Forestry Conservation which has had it for 5 or 6 years now, each year it is a task to get anybody to put in an essay. I don't know whether they are going to continue it beyond this year. They give $100.00 as a first prize, plus expenses to the convention. When I was in college that would certainly have been an inducement but it certainly doesn't seem to be now. But I think you can do something in the way of inviting students to these meetings and giving them sort of honorary memberships.

Student Papers Welcome

C. H. White: (American Walnut Manufacturers' Association): I've never had occasion to sponsor a contest of that type. We don't have an annual convention as such. Our group, even though very small, would welcome at any one of our regular monthly meetings the opportunity of hearing a student present a paper or enter into a discussion on veneer production, lumber production or something dealing with furniture; these various subjects would be well received by our people. I would be very happy to work with any of the schools and I would like to try it. I would like to have someone of that type present a paper of that type to our group. I'm sure we would have a better attendance if that were announced ahead of time.

L. J. Fitzpatrick: At our annual meeting of the National American Wholesale Lumber Association, held in the last 3 or 4 years, we have had junior achievement boys and girls from high school giving us a talk. The work that those boys and girls did was very outstanding and if the high school kids could do such a good job, it seems to me that college boys should also. I might further add that I'm on the program committee this year when we meet at White Sulphur Springs and I think our committee will welcome somebody from the colleges talking to our group about the problems they have. It is just this very point we are talking about—how to interest industry in the problems they have and one of the best ways is to talk to industry about it when they are in convention.

F. J. Hanrahan: How about planning a talk that would tell industry what the schools are doing? That would be something that the school itself could help the student work out and it could be a pattern that could be used for quite some time and then what we need is an eloquent speaker—a boy who can really put it across and describe to industry what the school is doing.

NLMA–TECO Program

Fred E. Dickinson: I would like to say one thing more in regard to contests and other industry attempts to interest students in industry. I think that the National Lumber Manufacturers Association has had by far the most successful program in interesting young men in industry and I'm thinking now of the TECO scholarship program which has been very successful and I think is a program of much more interest to the students than writing an essay because it gives him a chance to further his professional experience and professional background, and by the same token the National Lumber Manufacturers Association has in these young men who have been through that experience a ready-made group to appear before meetings to discuss several different things.

J. L. Muller: The essay contest doesn't work. We know that by sad experience. But why didn't it work? Why couldn't graduates or undergraduates sit down and prepare a paper of about 1,500 words, which is about 5 typewritten pages? It seems there was no interest involved. Nobody said to him this isn't just a matter of a $100.00 prize but you are getting national recognition. If you are interested in going into this industry as a profession and you can deliver your paper down here at this convention, you are in. You're one out of 10,000. You're known. But were these boys made conscious of this or was it just another piece of paper on which they wrote?

F. J. Hanrahan: We might take our lead from what some of the other schools are doing. I recently sat as one of three judges for a group of papers presented by mechanical engineering students. There were 29 schools represented. They had a local contest first and then they sent their prize students to regional and national meetings and I'll tell you some of those papers really staggered me and I didn't think the students could do the quality stuff that they did. And I'm sure any business man would have had exactly the same reaction to it. Some of those boys did better than some men with 10 or 15 years experience and they apparently had worked on it quite hard and they looked on it as part of their future development in the industry they wanted to go into too. They were looking at it from the standpoint of their future activities. Their viewpoint was a different type than you would expect from college students. That was the most impressive thing about it. To my way of thinking, that is as much of his college training as any course.

C. F. Van Epps: In line with what Mr. Hanrahan has said, the American Institute of Chemical Engineering presents a problem and has done this for 25 years, I think,—a problem of pretty substantial proportion for senior engineering students and in the curriculum of most chemical engineering groups the time is provided for work on that problem and again the quality of that work is in a large measure excellent. Credit is actually given for it and national prizes are awarded. The quality of that work is really outstanding in many, many instances.

Conclusion

At the conclusion of this discussion it was moved to accept the sub-group reports and to request the chairman and the secretary of each group to remain as a nucleus of a permanent sub-committee of the Education Section of the FPRS. Each chairman was further instructed to make his own recommendations for membership on his sub-committee and to follow up on the recommendations made at the Madison meeting. This motion was passed. The elected officers of each sub-committee are:

Group I—Type of Training to be Offered—C. F. Van Epps, Chairman; F. F. Wangaard, Secretary.

Group II—Industry Cooperation—Samuel M. Nickey, Jr., Chairman; A. D. Freas, Secretary.

Group III—How to Interest Qualified Young Men—F. E. Dickinson, Chairman, H. O. Fleischer, Secretary.

It is agreed that each sub-committee will have a further report to make at the time of the FPRS National meeting in Seattle, June 20–23.

College-Level Educational Programs for the Forest Products Industries[1]

FREDERICK F. WANGAARD

Professor of Forest Products, Yale University, New Haven, Connecticut

Summarizes curricula offered by 33 U. S. and 4 Canadian colleges to prepare men for employment in the forest products industries. Classifies schools with similar curricula in four groups and gives typical course programs for each.

THIRTY-THREE SCHOOLS in the United States and four in Canada offer 4-year undergraduate programs in one or more phases of forestry that prepare students for employment in the forest products industries. Nearly half of these schools also offer graduate work in fields relating to forest products and, in addition, there are two forestry schools that are strictly graduate in character having organized professional curricula in this field as well as facilities for specialized graduate study. Inasmuch as graduate study is usually of a highly individualistic nature, the discussion and classifications that follow are limited to the organized professional undergraduate and graduate programs offered by these schools. In a few instances specialized curricula directed toward some specific aspect of wood utilization, are offered in departments of a university other than forestry, conservation, or natural resources. These programs are noted later.

The traditional curriculum in forestry is commonly known as General Forestry, or sometimes as Forest Management. Educational programs of this type are typically broad in scope including the aspects of forestry relating to both the growing of the timber crop and its utilization. Although it may be said that such curricula permit little specialization, more emphasis is commonly placed upon silviculture and forest management than upon the utilization or technology of forest products. As the trend toward specialization in professional courses of study has developed, all schools of forestry have continued to offer a curriculum in General Forestry, but a substantial number of schools have limited their organized course of study to one of this type.

[1] Prepared in connection with the Industry-Education Conference held in Madison, Wisconsin, October 28–29, 1954.

The Author, Frederick F. Wangaard, received a B.S. degree from the University of Minnesota and M.S. and Ph.D. degrees from the New York State College of Forestry. He was employed by the U. S. Forest Products Laboratory from 1942–45 and was on the University of Washington faculty from 1936–42.

Group I

Schools which today offer only a general forestry program (although not necessarily designated by this particular name) insofar as preparation for the forest products industries is concerned, include the following:

Arkansas A. and M. College, University of California, University of Connecticut, University of Florida, University of Georgia, Université Laval, Louisiana Polytechnic Institute, University of Maine, University of Massachusetts, University of New Brunswick, University of New Hampshire, Oklahoma A. and M. College, Stephen F. Austin State College (Texas), University of Toronto, Utah State Agricultural College, Virginia Polytechnic Institute, State College of Washington (Pullman).

A detailed description of the course program in General Forestry as offered in each of these schools is not possible in a brief summary; however, a typical course of study is shown below. In addition to the technical courses listed, most schools make provision through a system of electives or requirements for students to take courses in the liberal arts, but no attempt is made to indicate studies of this type.

General Forestry (Group I)

First Year	Second Year
English Composition	General Physics
Algebra	Surveying
Trigonometry	Mapping
Botany	Dendrology
Zoology	Forest Protection
Inorganic Chemistry	Forest Entomology
Introduction to Forestry	Mensuration
Engineering Drawing	Forest Products
	Public Speaking

Summer Camp

Forest Surveying
Mensuration
Silviculture

Third Year	Fourth Year
Forest Soils	Forest Management
Silvics	Forest Valuation
Silviculture	Forest Economics and Policy
Economics	Logging
Wood Technology	Forest Utilization
Technical Writing	Forest Pathology

Electives in forestry, wood technology, botany, economics, business, etc.

Group II

Another large group of forestry schools has adopted an additional program (or programs) of study in the broad field of forest products, with the particular objective of providing training that will meet the needs of the forest products industries generally, but without special emphasis upon any one branch of industry. There is somewhat less uniformity, both in course content and terminology, among schools in this category than in the preceding one. Curricula are designated variously as Forest Products, Forest Utilization, Wood Utilization, Wood Technology, Forest Products Marketing, and Forest Products Industries. The following schools offer programs that may be classed in this general type:

School	Program
1. Alabama Polytechnic Institute	Wood Utilization
2. University of British Columbia	Forest Products and Wood Technology
3. Colorado A. and M. College	Forest Utilization
4. Duke University (2-year graduate program only)	Forest Products
5. University of Idaho	Wood Utilization Chemical phases Mechanical phases
6. Louisiana State University	Forest Utilization
7. Michigan College of Mining & Technology	Wood Technology Wood Utilization
8. University of Michigan	Wood Technology
9. University of Missouri	Forest Products Marketing
10. Montana State University	Forest Utilization
11. Oregon State College	Forest Products Production option Technology option
12. Pennsylvania State University	Wood Utilization
13. Purdue University	Wood Technology and Utilization
14. University of the South	Forest Products Industries
15. University of Washington	Forest Products Wood Technology Wood Industry
16. West Virginia University	
17. Yale University (2-year graduate program only)	Wood Technology–Utilization
18. Iowa State College	Wood Utilization

There is no clear-cut line of demarcation betwen the types of program designated by the various schools as Forest Utilization, Forest Products, Wood Industry, Wood Technology, etc. However, where in any particular school, separate curricula are offered in Forest Utilization, etc. and in Wood Technology, the former denotes a course of study in which emphasis is placed on business practices in the wood industries whereas the latter is concerned primarily with the technical study of wood properties and processes. Although the diversity among individual schools precludes the possibility of dealing here with the detailed program of each school, a composite curriculum in this category shapes up about as the following,[2] in which a close similarity will be noted to the first year in the General Forestry curriculum.

Forest Utilization—Wood Technology (Group II)

First Year

English Composition
Algebra
Trigonometry
Inorganic Chemistry
Botany
Dendrology
Introduction to Forestry
Engineering Drawing

Second Year

General Physics
Qualitative Analysis
Analytical Geometry
Calculus
Mensuration
Machine Shop
Public Speaking

Summer Field Work

Forest Products Industries

Third Year

Differential Equations
Organic Chemistry
Industrial Administration
Wood Anatomy and Identification
Statics
Strength of Materials
Economics
Technical Writing

Fourth Year

Thermodynamics
Logging
Lumber Manufacture and Distribution
Properties of Wood
Seasoning and Preservation
Veneer and Plywood
Forest Management
Forest Pathology

Electives in forestry, wood technology, engineering, industrial administration, business, etc.

Three of the schools listed, University of British Columbia, Oregon State College, and University of Washington, also offer a major course of study in Logging Engineering including work in civil and mechanical engineering in addition to the basic core of the General Forestry (Forest Management) curriculum indicated for Group I schools. At British Columbia this course of study is administered by the Faculty of Applied Sciences, at Washington and Oregon State by the School of Forestry.

[2] As in the case of Group I schools, the listing of courses given here does not include non-technical elective or required courses in the liberal arts, although most schools offer opportunity for such study.

Group III

Four schools have developed highly specialized curricula of which those of interest from the standpoint of the forest products industries include (in addition to Wood Utilization and Wood Technology) Retail Merchandising, Residental Construction, Pulp and Paper Technology, Plastics and Cellulose Chemistry, Wood Technology–Furniture, and Packaging Technology. These schools, together with their specialized curricula, are listed below.

Most of these specialized curricula are characterized by a common first year very similar to that previously described under Forest Utilization–Wood Technology (Group II). In these schools the curriculum in Wood Utilization or Conversion and Distribution includes many of the courses listed under Forest Utilization in Group II schools. In Group III schools, however, greater stress is usually placed on Industrial Engineering courses including Production Engineering, Industrial Organization, Production Control, Plant Layout, Time and Motion Study, and Quality Control. The curricula in Conversion and Distribution (Wood Utilization) and Merchandising and Light Construction share a virtually common second year, with a composite program about as follows:

Conversion and Distribution (Wood Utilization) (Group III)

Merchandising and Light Construction

Second Year

Analytical Geometry	Surveying
Physics	Public Speaking
Economics	Business Law
	Accounting

In the third and fourth years the separation of these specialized types of training is sufficiently distinct to require individual consideration.

Conversion and Distribution (Wood Utilization) (Group III)

Third Year

Finance
Logging
Wood Structure and Identification
Industrial Engineering
Heat and Power
Electrical Engineering
Lumber Manufacture
Forest Products
Woodworking Machinery

Fourth Year

Forest Pathology
Glues and Finishes
Kiln Drying
Forest Utilization
Wood Preservation
Uses of Wood
Lumber Salesmanship
Business Writing

Electives in wood utilization, wood technology, architecture, business, etc.

Summer Experience

Practical experience in the field

Merchandising and Light Construction[3] (Group III)

Third Year

Finance
Marketing
Transportation
Logging and Milling
Lumber Grading
Wood Structure and Identification
Properties of Wood
Building Materials and Methods
Woodworking Machinery
House Construction
Advertising

Fourth Year

Forest Pathology
Glues and Finishes
Seasoning and Preservation
Building Cost Estimating
Salesmanship
Forest Pathology
Retail Merchandising
Personnel Management
Real Estate

Electives in wood utilization, wood technology, architecture, business, economics, etc.

Summer Experience

Practical experience in the field

[3] At one school, as noted previously, this combination is divided into two distinct curricula: 1) Merchandising and 2) Residential Construction, permitting a greater degree of specialization.

School	Program
1. Michigan State College	Lumber and Building Materials Merchandising Residential Building Wood Utilization Packaging Technology Wood Technology
2. University of Minnesota	Building Materials Merchandising and Light Construction Wood Technology Wood Technology—Furniture
3. State University of New York College of Forestry (Syracuse)	Forest Products Conversion and Distribution Retail Merchandising and Light Construction Wood Technology Physics and mechanics major Chemistry major Anatomy major Pulp and Paper Technology Plastics and Cellulose Chemistry
4. North Carolina State College	Forest Management Utilization major Wood Technology Hardwood dimension and lumber major Veneer and plywood major Research and development major Wood Products Merchandising Building materials major Technical sales and service major Lumber and plywood major Pulp and Paper Technology

Wood Technology (Group III)

In this category of schools with highly specialized courses of study, the program in Wood Technology resembles that previously described for Group II schools with emphasis on the technical properties and processing of wood. Additional courses commonly offered in specialized Wood Technology curricula include Quantitative Analysis, Cellulose Chemistry, Advanced Wood Structure, Advanced Physics, Timber Mechanics, Design of Wood Structures, Photomicrography, Statistical Methods, and Quality Control.

Wood Technology–Furniture (Group III)

This curriculum, offered at the University of Minnesota, is a modification of the basic Wood Technology program in which emphasis is placed on business courses and industrial engineering. Consequently, a number of the more advanced technological courses are replaced by courses in Production Management, Industrial Plants, Method Analysis, Industrial Relations, and Elements of Supervision. A somewhat similar program aimed specifically at preparation for the furniture industry is given in the Department of Industrial Engineering at North Carolina State College. An arrangement whereby students desiring to prepare themselves specifically for the furniture industry is also available at the University of Michigan through summer session work supplementing the Wood Technology program.

Pulp and Paper Technology (Group III)

This curriculum, offered at two schools of forestry, is aimed specifically at technological preparation for the pulp, paper, and related industries. The first two years closely parallel the program in Wood Technology (Group II), with greater emphasis upon chemistry and specialized technology in the third and fourth years. Among the courses included in this part of the program are Physical Chemistry, Cellulose Chemistry, Electrical Engineering, Heat and Power, Pulp and Paper Technology including Paper Testing, Coloring, etc., Papermaking Fibers, Unit Processes, and Mill Management. Somewhat similar courses are offered in Chemical Engineering at the University of Maine (4 and 5-year programs) and at the Institute of Paper Chemistry (graduate only) in conjunction with Lawrence College at Appleton, Wisconsin.

Plastics and Cellulose Chemistry (Group III)

This option, offered only at the State University of New York (Syracuse), is a fourth year specialized program branching from the basic program in Pulp and Paper Technology. Specific additional courses include Plastics and Cellulose Technology and Plastics Technology Laboratory.

Packaging Technology (Group III)

A 4-year program in Packaging Technology, offered at Michigan State College, aims at the training of men for production and development work in the container industry. At this school, instruction in Forest Products is distinctly separate from that in Forestry, and courses in basic science and humanities have been introduced in place of the elementary forestry courses (Introduction to Forestry, Dendrology, Mensuration) ordinarily included in Wood Technology curricula. Except for the addition of specialized courses in Packaging, this program during the first two years somewhat resembles that outlined for Group II schools. The third and fourth years include a period of practical experience and concentrate on Packaging Materials and Packaging Technology, accompanied by courses in Statistical Methods, Industrial Engineering, Economics, Business Law, Cost Analysis, and Traffic Administration.

Engineering (Group IV)

A few engineering schools offer specialized undergraduate training in construction with some degree of emphasis on wood construction. The formally organized 4-year curriculum in Building Construction at Massachusetts Institute of Technology is indicated below:

First Year	Second Year
General Chemistry	Applied Mechanics
Physics	Physics
Western Civilization	Building Construction
Calculus	Calculus
Graphics	Differential Equations
English Composition	

Summer Camp

Surveying

Construction Surveying

Third Year	Fourth Year
Soils Mechanics	Structural Analysis
Fluid Mechanics	Electrical Engineering
Testing Materials Laboratory	Wood Design
Heat Engineering	Concrete Design
Building Construction	Economics
Materials— Metals Masonry Wood	Thesis
Job Management	
Structural Analysis	
Steel Design	

Electives in the humanities and social sciences.

Virginia Polytechnic Institute, through its Department of Wood Construction, offers specialized courses in Timber Engineering. These are primarily graduate courses but may be taken as electives by qualified undergraduates in engineering.

Quality Control in the Manufacture of Wood Products[1]

JAMES S. BETHEL
Member, FPRS Quality Control Committee

A preliminary report defining the quality control function and its usefulness in wood-using industries. Explains uses of statistical quality control to analyze variations in product quality.

THE WOOD USING INDUSTRIES include a very diverse group of manufacturing enterprises. They range in complexity from the production of railroad ties to the fabrication of fine furniture. The individual components of these industries range in size from the smallest portable sawmill employing five or ten men and having a capital investment of a few thousand dollars to the large pulp and paper company with a labor force of 4- or 5,000 employees and a capital investment of 50 to 60 million dollars.

It is difficult to generalize about a group of industries so diverse in size and character. In comparison with the metal-working and chemical industries, however, the average individual production unit among the wood-using industries is small. Perhaps because of this fact it has been traditional in these industries to make no clear distinction between the quality control function and the production function in the organization and operation of manufacturing facilities.

Separate Function

In most woodworking plants the production manager or superintendent and his supervisory staff are responsible for both production and quality control. In those industries where the techniques of mass production are better developed and more firmly established, it has long been recognized that quality control can best be assured by separating production and quality control functions and providing for an independent quality control program.

During World War II large numbers of wood-using industries found it worthwhile to adopt similar programs. In fact, some military procurement contracts required such an independent quality control organization. A few areas of the wood-using industry had adopted the principles of independent quality control even before this. The most notable example of this was perhaps the industry-wide program of the Douglas Fir Plywood Association. Since World War II interest in independent quality control programs has increased rapidly among the manufacturers of wood products.

The establishment of an independent quality control program requires that a clear distinction be made between the quality control function and related but independent design, engineering, production, and sales functions. Quality control may be described as including all of those activities engaged in by producers and/or consumers, individually or collectively for the purpose of assuring that the manufactured product conforms to accepted standards.

Evaluate and Interpret

Quality control ordinarily includes inspection, testing and control functions. The purposes of the inspection and testing functions are to determine quantitatively the characteristics of the product under consideration. The purpose of the control function is to evaluate and interpret the quantitative data obtained through inspection and testing so that production personnel can use it to maintain an operation which is producing product conforming to established standards. This must be true regardless of whether the inspections and tests are conducted by the manufacturer's quality control organization, an independent industry-sponsored quality control organization, or the consumer's quality control organization.

It must be recognized that inspection and testing per se do not necessarily imply quality control. Many inspections made in the manufacture of wood products are purely production operations. For example, the grading operation on the green chain of a sawmill is an inspection which accomplishes the purely production function of segregating products into established grades. On the other hand, an inspection which had as its objective to determine that the lumber grader is putting each piece of lumber into the correct grade as specified in the accepted grade standards would be a quality control function.

In the same way testing may be a research, engineering, production or quality control function. If a test of glue spread is made for the purposes of setting up a spreader, it is a production function. If it is made for the purpose of determining that the glue spreader is properly set up to provide conformance with accepted standards for glue spread, it is a quality control function.

Statistical Analysis

The most significant contribution which has been made to the field of quality control in recent years has been the adaptation of the powerful methods of statistical analysis to the problems of controlling the characteristics of manufactured products. These methods have made it possible to make rational evaluations of data obtained through the conduct of inspections and tests.

The statistical quality control chart provides a simple and easily understood analysis of the variation in product quality. It is possible to determine whether a process is capable of performing the function which it is expected to perform. It is possible to determine whether a process is in control, i.e., the variation from item to item represents a stable system of chance causes. It indicates when trouble in a manufacturing operation exists and provides guides to the solution of the problem. It provides information useful to the engineer in the preparation of specifications and standards and the setting of tolerances.

The wood-using industries have only recently adopted statistical quality control and there are still just a small minority of wood product manufacturers using it. The number of facilities making use of these techniques is, however, increasing very rapidly. To date applications of statistical quality control have been made in the manufacture of lumber, veneer, dimension stock, plywood, furniture, pulp and paper, and other wood products. It is probable that applications to other wood industries will be made in the near future.

The FPRS Quality Control Committee serves as a clearing house for new and improved methods of quality control as they are related to the manufacture of wood products.

[1] This report was approved for submission to the Annual Review issue of the Journal by the Quality Control Committee at the FPRS National Annual Meeting, Grand Rapids, Mich., May 5-7, 1954. Members of the Committee are: Charles S. Latimer, Chairman; Charles A. Bicking, J. S. Bethel, Robert H. Ripley, Richard C. Calahan, and Aubrey E. Wylie.

The Author, James S. Bethel, is Director, Wood Products Laboratory, and Professor of Wood Technology, School of Forestry, North Carolina State College, Raleigh. He attended the University of Washington and Duke University, holds B.S., M.S., and Ph.D. degrees.

Wood Technology Education and Research at the University of Michigan

FRED E. DICKINSON

Chairman, Department of Wood Technology, University of Michigan

Wood Technology as a professional field has developed rapidly during the last three decades. This has coincided with increasing interest of the wood-using industries in research and utilization of professionally-trained personnel, resulting in broader opportunities for young men. Realizing this dynamic situation, the Department of Wood Technology is ever striving to orient its program both in education and research to best benefit the profession and industry.

The Development of Wood Technology at Michigan

THE IMPORTANCE of the effective utilization of wood received formal recognition at the University of Michigan in 1887 when studies of wood anatomy were started. A year later research in timber physics was initiated under the direction of Mr. Filibert Roth and two years later the work was enlarged to include timber mechanics and a special study on the influence of tapping for turpentine on the mechanical properties of longleaf pine. This early work was under the auspices of the U. S. Division of Forestry and continued until 1893. The research resulted in some of the earliest bulletins published by the Division of Forestry on wood properties and uses.

In 1903 the Department of Forestry was established at the University and courses in forest utilization and timber physics were included in the curriculum. The attention given to wood utilization increased over the years and the addition in 1928 of a wood technology laboratory greatly enlarged the scope of work possible. Beginning in 1931, a program of study distinct from forestry was offered and in 1934 the name of the curriculum was changed to wood technology and further broadened to encompass additional aspects of the field of wood products so as to better prepare the graduates for industrial employment. Also in 1934, for the first time, the degrees, Bachelor's and Master's, were designated as having been earned in wood technology rather than forestry.

The fall of 1945 saw the inauguration of a special program in wood technology to prepare men for technical and executive positions in the furniture industry. This program which was suggested by the National Association of Furniture Manufacturers and the Furniture Manufacturers Association of Grand Rapids required students to take several selected courses in addition to the regular Wood Technology curriculum.

In 1950 the name of the School of Forestry and Conservation was changed to the School of Natural Resources and five departments established, namely Conservation, Fisheries, Forestry, Wildlife, and Wood Technology.

Research Program

The facilities of the Wood Technology Laboratory (Fig. 1) are used for the laboratory phases of formal educational courses and for academic and industrial research. While the first two uses of necessity take precedence over the last, a considerable amount of research for industry has also been conducted.

Academic Research: The major part of the academic research program is composed of projects carried on by graduate students under the guidance of the Wood Technology staff. The following is some of the student research recently completed or currently underway:

The effect of ray tissue on transverse shrinkage of red oak; the effect of time, temperature and relative humidity on the relief of casehardening stresses, the screw holding power of veneer and laminated wood panels; the effect of time and temperature on the relief of reverse casehardening stresses; the influence of specimen dimension on the delamination of lumber-core plywood; factors influenciny decay of treated gum ties; an analysis of a method for observing gap-filling properties of wood adhesives; fundamental factors influencing failures in furniture joints; influence of wood thickness on hysteresis; and growth stress in a coniferous stem.

In addition, research on the following problems is currently being carried on by the staff:

Influence on physical properties of wood of internal stress resulting from drying; the use of photographic techniques in measuring physical characteristics of wood surface; an analysis of a wood adhesive test method using a cross-lap specimen; and the influence of physical and mechanical properties of wood on its machinability.

Industrial Research: The financing of industrial research has been chiefly through contractual arrangements between the University, through its Engineering Research Institute, and the sponsoring company, association or government agency; however, some funds have come to the University for wood technology research directly as research grants with no particular study specified. Some of the various companies and agencies who have sponsored research during the past 15 years together with the studies conducted are as follows:

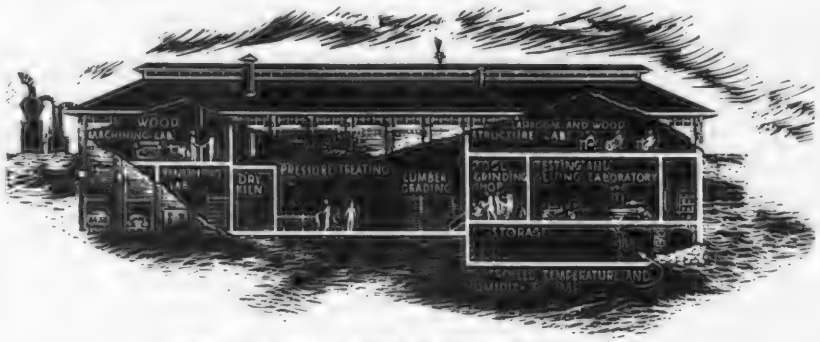

Figure 1.—Sketch of wood technology laboratory layout.

The Author, Fred E. Dickinson, holds a B.S. degree from the University of Minnesota, M.S. from Michigan State College, and Ph.D. from Yale University. He was formerly on the faculty of the School of Forestry, Yale University, and has been associated with forest products industries in the Lake States, California, the Northeast, and the South.

National Advisory Committee on Aeronautics—Static loading of beams.

Tennessee Valley Authority—Use of walnut flour as a filler in plastics.

Veneer Association—Development of a new type of molded plywood construction.

National Association of Furniture Manufacturers—Evaluation of adhesives for furniture, development of an adhesive test method, and preparation of a gluing manual.

Kroehler Foundation—Effect of cutter speeds and knife angles in shaping operations.

Plaswood Corporation—Evaluation of a chip-core type of board.

Wolverine Finishes Corporation—Preparation of a manual on finishing materials and procedures.

Buss Machine Works—Study of the characteristics of the Buss planer.

American Saw and Tool Company—Evaluation of saw blades for better performance in cutting.

Carborundum Company—Machining of wood with coated abrasives.

In addition, the Department has evaluated a variety of products for various manufacturers and is the agency for testing the performance of toxic-water repellants for the National Woodwork Manufacturers Association. Currently a project is underway with the Hines Lumber Company to study the stabilizing effect of several materials on panel doors.

All industrial research projects are supervised by the staff, and research assistants, generally graduate students, are employed to carry on the work.

Laboratory Facilities

The Wood Technology Laboratory is a factory-type building located on the campus and containing approximately 20,000 square feet of floor space. Here adequate classroom space, equipment, and instruments are available for the laboratory phases of the formal courses as well as for academic and industrial research dealing with most types of wood technology problems.

One section of the Laboratory houses facilities for wood chemistry (Fig. 2), a large section devoted to wood structure and identification (Figs. 3 and 4), a drawing room which is used in studies of design of wood-working machinery, and offices for graduate students and laboratory assistants. Also on this floor is a well-equipped photographic darkroom.

In the gluing and mechanical properties laboratory (Fig. 5) is located a large variety of wood-gluing apparatus including hot and cold presses, a high frequency unit, testing equipment for plywood and laminated material and various pieces of instrumentation used in adhesive evaluation. Mechanical testing equipment includes two universal testing

Figure 2.—Facilities are available for formal course work and research in wood chemistry.

Figure 3.—Studies of wood structure are an important part of the education of a wood technologist.

Figure 5.—A view of the gluing and mechanical properties laboratory.

Figure 4.—Student preparing thin sections of wood on a microtome preparatory to study of anatomical features. Photomicrophy equipment and research microscopes are available to aid studies of this nature.

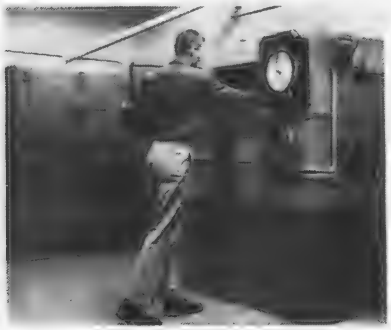

Figure 6.—A small controlled temperature–humidity unit used in kiln drying studies.

Figure 8.—Equipment for studies of wood finishing materials include a forced-draft spray booth and various types of spraying equipment.

Figure 9.—Production type wood-working machines adapted for research make possible fundamental studies in wood machining.

machines, a toughness testing machine and electrical strain gauge apparatus. A weighing room equipped with balances and drying ovens is adjacent to this laboratory.

Kiln drying studies are carried on in a 1500 board-foot capacity, internal fan kiln located on the ground floor and in a small controlled temperature-humidity unit (Fig. 6). The necessary instrumentation including a potentiometer, velometer, and moisture meters are available for these studies. Also located on the ground floor is apparatus for wood treating including pilot-plant size pressure treating equipment, dry-vac equipment, an auto-clave, and various testing equipment (Fig. 7).

One section of the laboratory is devoted to studies of finishing materials, their properties and performance. Equipment for application of coatings (Fig. 8), determining properties of materials and measuring performance of applied coatings is available.

The machining of wood efficiently and accurately is undoubtedly one of the foremost concerns of the wood-using industries. In order to acquaint students with various types of machines and to permit intensive research in this field, the wood machining laboratory is equipped with a number of production-type machines including planers, jointer, router, shaper, band saw, miter and cut-off saws, belt sanders and drill presses which have been especially adapted to allow measurements of power requirements and cutting efficiency (Fig. 9). In addition a variable-speed frequency changer makes it possible to operate the machines through a wide range of speeds to study the effects of varied cutter and feed speed on the efficiency of removing material as well as on the quality of the resultant machined surfaces. As instrumentation is very important in machining studies, the laboratory is equipped with power measuring and recording devices, stroboscopes, sensitive surface analyzers and various precision gauges and tools.

In addition to the above equipment a small but well-equipped machine shop containing a precision engine lathe, milling machine and numerous saw- and knife-grinding machines makes it possible to maintain laboratory equipment in excellent working condition as well as to prepare special tools and jigs for research.

Several areas of the laboratory are devoted to material storage and in addition there are four walk-in controlled temperature-humidity rooms which are used for conditioning stock for testing as well as for cycling material to determine the influence of changing moisture content.

A circular sawmill owned by the School of Natural Resources is available for cutting test material from logs as well as for milling studies.

Figure 7.—Studies of methods and materials which will protect wood against moisture, fire, and insect and fungus attack are an important phase of wood technology. Here a swellograph is being used to measure the effectiveness of a water-repellent treatment.

Educational Program

Wood Technology is a profession concerned with the properties, processing and utilization of wood, a material of organic origin and consequently of variable behavior. Since the organic nature of wood influences its utilization in either chemically or mechanically fabricated products, the wood technologist's education must include a strong foundation in the natural as well as the physical sciences. To make the problem more complex, the wood-using industry is essentially one of small firms; consequently the wood technologist in industry must often supervise personnel, make up budgets and contact the consuming public. Thus his education must also include the social sciences and humanities.

For a number of years the curriculum in wood technology at the University of Michigan has stressed the use of wood in fabricated products and graduates of the course have for the most part been employed in the secondary wood-using industry. Starting with the fall semester of 1955, a second curriculum will be offered. This latter one will include as part of the professional course work several courses in forestry in addition to those in wood technology and should be attractive to those students interested in the primary wood-using industries

whether it be in the areas of production or merchandising.

The two curricula, designated as Primary and Secondary, are designed to include the minimum number of professional courses commensurate with giving the student sufficient professional knowledge and to include the maximum amount of social science and humanities, physical and biological science and mathematics as well as a sizeable number of elective hours to permit the student to better prepare himself for some particular activity as marketing, plant management or quality control. As four or more years of college education in a professional field can never hope to give the graduate all of the answers to the problems he will encounter in the field, the important thing is that of giving him the tools by which he can arrive at the answers. Thus in the professional courses the emphasis is on fundamental concepts rather than the vocational aspects. The general composition of the two curricula which lead to Bachelor of Science degrees are given below.

A unique aspect of the educational program is an inclusion of a high proportion of laboratory time as part of each formal course in wood technology. For example, a three-semester hour course includes two one-hour lectures and a four-hour laboratory period. The long laboratory periods permit intensive experimental study by the students of the various properties and processing techniques of wood.

An important part of the undergraduate program is an eight-weeks summer session concerned with plant studies. This session, which is required of all those following the Secondary curriculum and is elective for students in the Primary curriculum, is normally taken between the Junior and Senior years. Six weeks are spent in Grand Rapids, Michigan, studying the wood-using industries in that area and the other two weeks are spent in two one-week trips, one to visit the Chicago Furniture Market, the Forest Products Laboratory and plants in Wisconsin, and the other to visit wood-using plants in other sections of the country. On this latter trip, factories and mills have been visited in the Louisville-Memphis area, the High Point area and in the states of New York and Pennsylvania during the past several years.

Graduate Education

Graduate work is offered both at the master and doctorate level. The Master of Wood Technology degree is administered in the School of Natural Resources, while the Master of Science and the Doctor of Philosophy degrees are administered in the Graduate School. From 1934 through 1954, 54 advanced degrees in wood technology have been awarded. Graduate work is becoming more and more desirable in this field as opportunities for employment develop and as the profession advances.

Extension

The Department has for several years offered extension courses for industry both on and off the campus. Since 1945 a course in "Funiture Technology" has been given each winter in Grand Rapids for the furniture industry. Topics of current interest as well as a coverage of some of the fundamental aspects of wood are included in the course. During the last two years courses of interest to the retail lumber dealers as well as to those in other phases of wood utilization have been given in Detroit. Subjects covered include plywood manufacture and properties, lumber grading, wood finishing, and wood as a structural material. Each summer a one-week course on "Trouble Shooting" is given on campus. This very intensive course deals with the problems which are encountered in gluing, machining, finishing, and drying as well as background information on wood properties.

Staff

Glen P. Bruneau, B.S. (Forestry) University of Michigan, is Supervisor of the Wood Technology Laboratory. He has had experience with the U. S. Forest Service, the Ford Motor Company and the King–Seeley Corporation.

Fred E. Dickinson, B.S. (Forestry) University of Minnesota, M.S. (Forest Products) Michigan State College, Ph.D. (Forest Products Economics) Yale University, is in charge of the work in lumber manufacture and marketing and wood drying. He was employed as a technologist at the Forest Products Laboratory during World War II, served as a Civilian Technologist in Packaging to the War Department in France in 1945, and was a mem-

PRIMARY WOOD PRODUCTS CURRICULUM

Subject	Semester Hours	
English Composition	6	
Mathematics		
Algebra and Trigonometry	4	
Drawing	1	
Biological sciences		
Elements of Botany	4	
Physical sciences		
General Chemistry	8	
Physics	8	
Social sciences and humanities		
Principles of Economics	6	
Accounting	3	
Language (English and foreign language and literature, speech, journalism)	6	
Other (elective)	6	52
Forestry		
Forest Surveying and Mapping (Summer Session)	3	
Forest Biology (Summer Session)	5	
Forest Mensuration (Summer Session)	4	
Tree Identification and Distribution	3	
Foundations of Silviculture	4	
Forest Economics, Forest Management, or Forest Administration, (any two)	6	
Logging and Milling	3	28
Wood Technology		
Structure of Wood	3	
Identification of Wood	2	
Physical and Mechanical Properties of Wood I, II	7	
Lumber and Dimension Stock Manufacture, Grading and Merchandising	4	
Plywood and Laminated Construction	4	
Wood-using Industries	2	
Air-Drying and Kiln Drying of Wood	3	25
General electives		27
		132

SECONDARY WOOD PRODUCTS CURRICULUM

Subject	Semester Hours	
English Composition	6	
Mathematics and Engineering		
Algebra and Trigonometry	4	
Additional Mathematics	3-4	
Drawing	4	
Engineering Materials and Processes	5	
Factory Management	3	
Biological Sciences		
Elements of Botany	4	
Physical Sciences		
General Chemistry	8	
Physics	8	
Social Sciences and Humanities		
Principles of Economics	6	
Accounting	3	
Language (English and foreign language and literature, speech, journalism)	6	
Other (elective)	6	66-67
Forestry		
General Forestry	3	
Tree Identification and Distribution	3	6
Wood Technology		
Structure of Wood	3	
Identification of Wood	2	
Machining of Wood	3	
Physical and Mechanical Properties of Wood I, II	7	
Air Drying and Kiln Drying of Wood	3	
Lumber and Dimension Stock Manufacture, Grading and Merchandising	4	
Plywood and Laminated Construction	4	
Design of Woodworking Machinery	3	
Wood Chemistry	4	
Wood-Using Industries—Plant Studies (Summer Session)	8	41
General Electives		18-19
		13

ber of the faculty of the Yale School of Forestry. His industrial experience includes consulting as well as several years with the lumber industry in the Lake States and California.

Norman C. Franz, B.S. (Forestry) New York State College of Forestry, M.W.T., University of Michigan, is in charge of the work in wood machining and finishing. Prior to joining the faculty he served as Research Associate, University of Michigan, conducting wood machining research.

Alan A. Marra, B.S. (Wood Technology) and M.S. (Wood Technology), New York State College of Forestry; Ph.D. (Wood Technology) University of Michigan, is in charge of work in gluing, wood chemistry, aggregate boards, and wood preservation. He served as research assistant at Michigan State College, as Project Engineer at Engineering Research Corp., as Technical Director of Pluswood, Inc., and as Supervisor, Sales Service Laboratory, Monsanto Chemical Co. Prior to joining the faculty he was Research Engineer, University of Michigan, conducting research in adhesives.

Stephen B. Preston, B.S. (Forestry) and M.F. (Forest Management) Colorado A & M College, M.S. (Wood Technology) and D. For. (Wood Technology) Yale University, is in charge of work in wood anatomy and identification and physical and mechanical properties of wood. He was associated with the Texas Longleaf Co., and served as Assistant in Instruction and Research Assistant, Yale University.

Publications

Much of the research findings resulting from industrial research is submitted to the sponsoring companies in the form of unpublished reports. In some instances, these findings have been released by the sponsors. In the instances where agreeable to the sponsor, results have been published in various scientific and trade journals. Student and faculty research has been published in journals and in the bulletin series of the School. Recently a series of notes entitled "Michigan Wood Technology" was started by the Department for the publishing of abstracts of master's theses as well as short research papers produced by the faculty.

Industry Cooperation

The Department of Wood Technology has been fortunate in having close cooperation with representatives of industry both in its educational and research programs. Particularly noteworthy has been the cooperation received from the National Association of Furniture Manufacturers, the Furniture Manufacturers Association of Grand Rapids, and the National Woodwork Manufacturers Association. Frequent meetings are held with representatives of these groups to discuss matters of common interest in wood technology education and research. Through the efforts of the furniture industry, the Department has received a number of scholarship and fellowship grants as well as funds for research.

Durability of Fortified Urea-Resin Glues in Plywood Joints[1]

R. F. BLOMQUIST and W. Z. OLSON

Chemist, and Technologist, Forest Products Laboratory,[2] Forest Service, U. S. Department of Agriculture

Discusses advantages of fortifying hot-press urea-resin glues with melamine resin and resorcinol to improve durability in plywood joints. Tests were conducted under laboratory controlled temperature and humidity conditions, and by exposing to weather.

A STUDY WAS CONDUCTED to investigate the possible advantage of incorporation of various proportions of melamine resin and resorcinol to improve the durability of conventional hot-press urea-resin glue joints in plywood under each of several controlled laboratory conditions and under exterior weathering. Ten percent resorcinol and 20 percent melamine resin, the lowest proportions studied, were found to have definite value in improving the resistance of the straight urea-resin glue joints under laboratory conditions of elevated temperature and of high humidity and to exterior weathering. Generally, some further improvement was obtained in proportion to the amount of fortifier added: but, except in a few cases, no urea-fortifier combination fully equalled the performance of a straight melamine-resin glue.

Introduction

Previous work at the U. S. Forest Products Laboratory[3] has indicated that phenol–, resorcinol–, and melamine-resin glues are the most durable of the currently available woodworking glues. These glues, when properly used, are capable of forming joints that will resist separation under severe conditions of exposure and in destructive tests after such exposure. When joints do separate, as a result of such treatment, failures are in the wood rather than in the glue. Unextended urea-resin glues have been shown[3] to lack this high degree of permanence under outdoor weathering and after laboratory exposures involving elevated temperature, such as 158° F., and high relative humidity conditions at normal room or elevated temperatures. Some limited tests[3] with so-called "fortified" urea resins containing undetermined, but probably small, amounts of melamine resin or resorcinol added to conventional urea-resin glue, indicated that such "fortification" tended to improve the durability of the urea-resin glue under these more critical exposures, although not to a point comparable to that of the phenol–, melamine–, and resorcinol-resin glues. Results of other studies[4,5] indicated that increasing the

[1] This study was conducted in cooperation with the Research and Development Division, Office of the Quartermaster General; and the paper presented at FPRS Ohio Valley Section Meeting, Cincinnati, Ohio, October 14 and 15, 1954.

[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsn.

The Authors: Richard F. Blomquist is head of the Glues and Gluing Section, Division of Wood Preservation. He received B.A. degree from Coe College, M.S. and Ph.D. degrees from University of Iowa.

Warren Z. Olson is engaged in research in the properties and characteristics of wood glues. He received B.S. degree from the University of Wisconsin, is author of several FPL publications.

[3] Wangaard, F. F. Summary of Information on the Durability of Water-Resistant Woodworking Glues. Forest Products Laboratory Report No. 1530, December 1946.

[4] Lecher, S. M. Effect of Boiling for Various Periods of Time on the Strength of Joints in Birch Plywood Bonded with Urea Glue Fortified with Varying Amounts of Melamine and Resorcinol. Forest Products Laboratory Report No. 1549, December 1946.

[5] Rider, S. H., and Kozdemba, S. E. Boil Resistance of Blended Urea-Melamine Wood Adhesives. Forest Products Research Society, 1954. Preprint No. 576.

amount of melamine resin or resorcinol added to a urea-resin glue improved its resistance to prolonged boiling in water, a test condition often used in a rapid comparison of various types of resin glues.

Because adequate information was lacking to relate the type and amount of such fortifying agents for urea-resin glues to their durability under the more severe laboratory-controlled exposures and to outdoor weathering, the following series of tests was undertaken. For this purpose, one standard commercial powdered urea resin, without incorporated catalysts, fillers, or extenders, was selected and then modified by addition of known amounts of either a standard melamine resin, without catalyst or filler, or crystal resorcinol and paraformaldehyde.

Procedures

Preparation of Specimens: Ten laboratory-formulated glues, based on one urea resin, were used in making the test specimens for this study. The formulas for these glues are included in table 1. All glues were of the hot-press type. These glues were used in making three-ply 12- by 12-inch panels of 1/16-inch yellow birch veneer for the laboratory-controlled tests. In addition, 2 three-ply 24- by 24-inch panels of 1/16-inch yellow birch, 2 of Douglas-fir, 2 of yellow-poplar veneers, and 2 five-ply 24 by 24-inch panels of 1/8-inch veneers of these 3 species were prepared with each of the 10 glues for the exterior weathering tests.

The panels were made under the following conditions:

Moisture content of the veneers: 6 percent

Average amounts of glue spread per 1,000 square feet of glue line: 44 to 54 pounds

Assembly time: 30 minutes closed

Pressure: 150 pounds per square inch

Platen temperature: 250° F.

Pressure period: 3/16-inch panels, 6 minutes; 5/8-inch panels, 10 minutes

All panels were conditioned for at least 1 week at 80° F. and 30 percent relative humidity before being trimmed for test-fence exposure or cut into shear test specimens. Thirty standard shear test specimens were cut from each of the 12- by 12-inch birch panels for initial quality tests and for exposure to controlled temperature and humidity conditions. These specimens were then subdivided into representative groups for the various required tests by a process of random selection. The 24- by 24-inch panels were trimmed to 18- by 18-inch panels for test-fence exposure and standard shear specimens for initial quality tests were cut from the trimmings.

Initial Quality Tests: The following initial tests were made for the controlled exposure experiments: 1. Dry. 2. Wet after 48 hours of soaking in water at room temperature. 3. Wet after 48 hours of soaking in water at room temperature, followed by 3 cycles, consisting of 8 hours of drying at 145° F. ± 5° F.) and 16 hours of soaking in water at room temperature.

Table 1.—COMPOSITION IN PARTS BY WEIGHT OF GLUES USED IN PREPARING PLYWOOD TEST SPECIMENS

Glue No.	Urea resin[1]	Melamine resin[2]	Resorcinol[3]	Ammonium chloride	Paraform-aldehyde[4]	Water	Walnut-shell flour
1	100	0	0	0.5	0	60	10
2	80	20	0	.5	0	60	10
3	60	40	0	.5	0	60	10
4	40	60	0	.5	0	60	10
5	20	80	0	.5	0	50	10
6	0	100	0	0	0	50	10
7	90	0	10	.5	4.1	45	10
8	80	0	20	.5	8.2	40	10
9	60	0	40	.5	16.4	33	10
10	40	0	60	.5	24.6	28	10

[1] A neat urea-resin powder without filler or catalyst.

[2] A neat melamine-resin powder without filler or catalyst.

[3] U.S.P. resorcinol.

[4] The resin-grade paraformaldehyde was added to give a ratio of 1.5 moles formaldehyde per 1.0 mole resorcinol.

Table 2.—RESULTS OF TESTS OF INITIAL QUALITY OF BONDS IN BIRCH PLYWOOD SPECIMENS MADE WITH UREA-RESIN AND FORTIFIED UREA-RESIN GLUES AND EXPOSED TO LABORATORY CONDITIONS

Glue No.	Amount and type of fortifier	Joint strengths and percentages of wood failure[1]			
		Dry[2]	48-hour water immersion[3]	Cold-soak cycle[4]	Boil cycle[5]
1	None	431-74	427-95	.....	0-0
2	20 percent melamine resin	449-87	476-99	475-99	251-7
3	40 percent melamine resin	438-95	458-98	414-99	295-14
4	60 percent melamine resin	430-94	482-95	454-99	340-34
5	80 percent melamine resin	426-92	426-100	.....	342-68
6	100 percent melamine resin	399-94	493-100	.....	434-99
7	10 percent resorcinol	410-99	454-94	447-98	255-5
8	20 percent resorcinol	410-97	474-98	463-99	364-25
9	40 percent resorcinol	415-98	491-98	483-100	449-96
10	60 percent resorcinol	411-97	558-98	498-100	495-99

[1] In this table the value before the dash is the average shear strength in pounds per square inch; the value after the dash is the average estimated wood failure in percent. Each value is the average for 10 to 32 specimens. No data were available for the blank spaces.

[2] Tested dry.

[3] Tested wet after soaking for 48 hours in water at room temperature.

[4] Tested wet after soaking for 48 hours in water at room temperature, followed by 3 cycles, each consisting of drying for 8 hours at 145° F. (± 5° F.) and 16 hours of soaking in water at room temperature.

[5] Tested wet after cooling to room temperature following 4 hours of immersion in boiling water, 20 hours of drying at 145° F. (± 5° F.), and 4 hours of immersion in boiling water.

Table 3.—RESULTS OF CONTROL TESTS ON SPECIMENS CUT FROM TRIMMINGS OF PANELS PREPARED FOR EXPOSURE TO WEATHER

Glue No.	Amount and type of fortifier		Specimen construction		Joint strengths and percentages of wood failure[1]													
					Yellow birch						Douglas-fir				Yellow-poplar			
	Melamine resin	Resorcinol	No. of plies	Thickness of ply	Dry[2]	Wet[3]	Cold-soak cycle[4]	Boil cycle[2]	24-hour boil[6]	48-hour boil[7]	72-hour boil[8]	Dry[2]	Wet[3]	Cold-soak cycle[4]	Boil cycle[2]	Dry[2]	Wet[3]	Cold-soak cycle[4]	Boil cycle[2]
	Percent	Percent		In.														
1			3	1/16	423-93	403-100	379-92	0-0	0-0	0-0	0-0	213-100	247-89	224-78	0-0	300-100	212-100	192-100	0-0
1			5	1/8	402-80	443-92	422-73	0-0				207-94	230-86	213-71	0-0	251-100	266-100	255-100	0-0
2	20		3	1/16	450-97	459-96	441-83	163-0	78-0	0-0	0-0	239-100	286-100	261-97	142-14	326-100	267-100	263-100	99-1
2	20		5	1/8	406-78	424-98	389-98	208-10				232-99	243-99	221-99	110-11	265-100	257-100	233-100	141-11
3	40		3	1/16	437-100	428-100	384-80	242-0	182-0	95-0	41-0	220-100	277-100	256-100	197-75	279-100	242-100	208-90	120-15
3	40		5	1/8	417-87	408-100	381-86	304-42				227-98	262-96	257-99	212-80	276-98	210-100	194-100	154-8
4	60		3	1/16	442-99	423-100	390-91	271-0	173-0	104-0	44-0	220-100	279-100	263-99	194-14	329-100	218-100	206-100	174-7
4	60		5	1/8	408-57	440-89	410-93	310-38				246-98	261-100	236-100	195-84	304-100	296-100	276-100	241-9
5	80		3	1/16	442-98	376-100	371-91	296-25	211-6	142-0	72-0	232-100	255-100	226-99	190-72	321-100	242-100	238-100	218-9
5	80		5	1/8	384-98	367-99	357-97	299-62				228-99	274-100	265-100	221-100	291-100	278-100	262-100	236-1
6	100		3	1/16	466-100	403-100	403-100	367-100	384-99	280-27	178-0	228-99	270-100	263-100	247-99	335-100	265-100	265-100	246-100
6	100		5	1/8	422-100	430-100	447-100	381-99				226-97	276-100	245-100	245-99	309-100	297-100	273-100	218-1
7		10	3	1/16	490-99	441-99	425-98	215-0		75-0	54-0	218-100	274-96	273-92	121-1	325-100	270-100	250-100	94-1
7		10	5	1/8	442-84	388-97	393-94	200-2				261-96	294-98	260-98	121-13	300-100	244-100	217-100	156-7
8		20	3	1/16	486-100	433-100	426-99	320-19		214-0	177-0	226-100	306-100	291-99	242-79	329-100	248-100	240-100	206-6
8		20	5	1/8	465-59	468-95	451-92	286-4				232-97	287-100	250-92	197-81	313-100	314-100	289-100	238-8
9		40	3	1/16	481-99	454-100	431-98	408-99		335-99	335-98	221-98	289-99	280-95	259-95	315-100	261-100	259-100	240-10
9		40	5	1/8	436-94	538-99	496-98	433-97				218-98	300-96	270-96	231-99	288-100	312-100	266-100	236-10
10		60	3	1/16	458-99	462-98	463-99	414-87		376-99	353-92	220-100	287-98	266-98	245-93	303-96	299-100	265-98	257-6
10		60	5	1/8	371-86	516-96	486-90	422-62				232-97	270-99	251-98	214-97	273-94	285-100	257-100	234-9

[1] In this table, the value before the dash is the average shear strength in pounds per square inch; the value after the dash is the average estimated wood failure in percent. Each value is the average for a total of 10 specimens from 2 panels. Where no data are given, tests were not conducted.

[2] Tested dry.

[3] Tested wet after 48 hours of soaking in water at room temperature.

[4] Tested wet after 48 hours of soaking in water at room temperature, followed by 3 cycles, each consisting of 8 hours of drying at 145° F. (± 5° F.), followed by 16 hours of soaking in water at room temperature.

[5] Tested wet after cooling to room temperature following immersion in boiling water for 4 hours, drying for 20 hours at 145° F. (± 5° F.), and immersion again in boiling water for 4 hours.

[6] Tested wet after cooling to room temperature following immersion in boiling water for 24 hours.

[7] Tested wet after cooling to room temperature following immersion in boiling water for 48 hours.

[8] Tested wet after cooling to room temperature following immersion in boiling water for 72 hours.

4. Wet after 4 hours of immersion in boiling water, 20 hours of drying at 145° F. ± 5° F.), and 4 hours of immersion in boiling water, then cooling to room temperature before testing.

Note: Tests 3 and 4 are the conventional procedures used for evaluation of exterior-type plywood in Commercial Standard CS 45–48 for Douglas-fir Plywood and for Type I plywood in Commercial Standard CS 35–49 for Hardwood Plywood.

Since earlier work[4] had indicated some merit to longer periods in boiling water as a means of characterizing such fortified urea-resin glues, groups of specimens cut from the trim of panels prepared for weather exposure were also subjected to the following additional tests:

5. Wet after 24 hours of immersion in boiling water and then cooling in water to room temperature.

6. Wet after 48 hours of immersion in boiling water and then cooling in water to room temperature.

7. Wet after 72 hours of immersion in boiling water and then cooling in water to room temperature.

Exposures: Representative groups of shear test specimens made with all glues were exposed to the following laboratory-controlled conditions, which were selected as representative of the more severe service conditions to which durable glues might be subjected.

A. Continuously at 20 percent relative humidity and 158° F.

B. Continuously at 97 percent relative humidity and 80° F.

C. To a repeating cycle consisting of 2 weeks at 97 percent relative humidtiy and 2 weeks at 30 percent relative humidity, both at 80° F.

D. To a repeating cycle consisting of 4 weeks at 90 percent relative humidity and 4 weeks at 30 percent relative humidity, both at 80° F.

For the exterior exposure tests, four 18- by 18-inch panels of each of Douglas-fir, yellow birch, and yellow-poplar, made with each glue, were selected. Two of each set were of three-ply, 3/16-inch construction and 2 were of five-ply, 5/8-inch construction. Panels were mounted vertically on a test fence, facing south, near Madison, Wis. Panels were installed during the summer and were given no paint or mechanical protection.

Test Periods: At 6-month intervals a representative group of 5 yellow birch specimens with each glue was removed from each of the laboratory-controlled exposures and tested without reconditioning, except that specimens from exposure A were cooled to room temperature. At each period, an additional 5 specimens with each glue were tested wet after soaking for 48 hours in water at room temperature following removal from each exposure.

In July of each year, the edges of all panels exposed to weather were examined for delamination. The boundaries of any delamination were determined by inserting a feeler gage and plotting measurements on a diagram of the panel drawn to scale. Areas of delamination were then determined, and results were reported as percentages of the total glue-joint area.

Results and Discussion

The results of initial quality tests on birch specimens are included in table 2 and results of initial quality tests on all three species are given in table 3. The high joint strengths and percentages of wood failure in the dry tests and tests after 48 hours of soaking in water at room temperature indicate the consistently high quality of the specimens before exposure to controlled conditions and to the weather.

In tables 2 and 3 the results of tests after the cold-soaking cycle (test 3), like those of the dry and wet tests (Nos. 1 and 2), showed uniformly high quality and failed to show consistent distinction between the different amounts of fortification. On the other

hand, results after the boil cycle test (test 4) and the various continuous boil tests (tests 5, 6, and 7 of table 3) generally showed increased joint strength and percentages of wood failure with increasing percentages of both melamine resin and resorcinol. Results of tests 6 and 7 are of interest because they indicate that a straight melamine-resin glue undergoes a very significant loss in joint quality after 48 and 72 hours of boiling in water, and that a urea resin fortified with 40 and 60 percent resorcinol shows considerably greater resistance to such prolonged boiling than does a straight melamine-resin glue.

The effect of the laboratory-controlled exposures on the shear strength of the birch plywood joints over a 4 year period is shown in figures 1 through 4. For this method of presentation, the actual percentages of initial shear strength retained were first plotted and a smooth curve fitted for each glue in each exposure. These smooth curves were then replotted together for more convenient comparison. This method of expressing results as percentages of initial strength retained seems justified since the initial dry shear strengths were in close agreement (399 to 449 p.s.i. and 74 to 99 percent wood failure). However, wet strengths were also in close agreement (426 to 493 p.s.i.), except for glue No. 10, which had an unusually high strength of 558 pounds per square inch. Previous experience in interpretation of similar trends in durability tests would indicate caution in attempting to extrapolate such curves for longer periods of exposure. To aid in interpretation of these curves, the actual average wood-failure values observed after the 4-year tests are shown on the ends of each curve. Wood-failure values for shorter periods of exposure are not included. Changes in joint strength and wood-failure values were found to be quite consistent in each of the 4 exposures, and values after 4 years of exposure were nearly always in line with previous trends. Therefore, as an additional aid in interpretation of these figures and trends, the joint strengths and percentages of wood failure after 4 years are given in table 4.

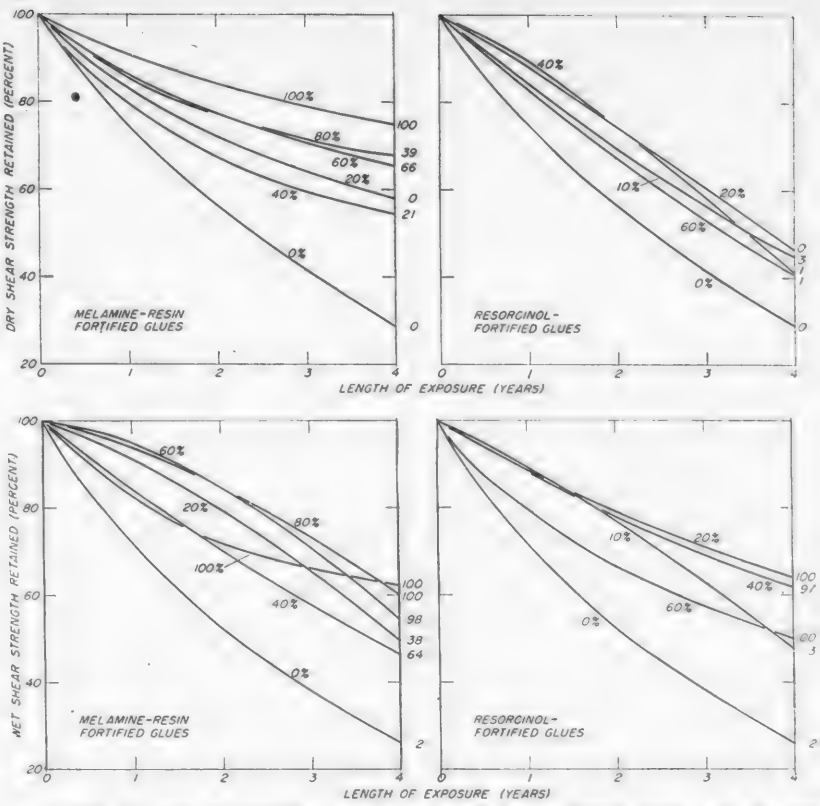

Figure 1.—Effect of exposure at 158° F. and 20 percent relative humidity on the shear strength of yellow birch plywood joints made with urea-resin glues containing various proportions of fortifier. (Number at end of each curve is the average percentage of wood failure observed in the specimens tested at 4 years.)

Exposure to Elevated Temperature: In this continuous exposure at 158° F. and 20 percent relative humidity (fig. 1), the decrease in strength of the unfortified urea-resin glue (No. 1) was considerably more rapid than for any of the fortified glues. The melamine-resin fortified glues in this series all showed a more gradual decline in joint strength in both dry and wet tests than did the unfortified glue. In the tests, this trend was accompanied by decreasing percentages of wood failure, indicating an effect on the glue more than on the wood itself. The rate of decline in strength was generally in proportion to the amount of urea resin present. However, in the wet tests, the straight melamine resin (glue 6) showed somewhat greater decreases in percentages of initial strength retained after exposures of less than 4 years than did some of the melamine-urea resin combinations. This trend was reversed after 4 years of exposure. It may be noted that the 60, 80, and 100 percent melamine-resin glues (glues 4, 5, and 6) had averages of 98 percent and higher wood failures in these wet tests after the 4 years of exposure, thus indicating that the effect of the exposure on the wet strength of the glue was concealed by the low wet strength of the wood. The most consistent improvement in durability in this exposure appears to be accomplished by the addition of 20 percent fortifier, and in-

Table 4.—ACTUAL TEST RESULTS AFTER 4 YEARS OF EXPOSURE TO 4 LABORATORY-CONTROLLED CONDITIONS OF YELLOW BIRCH PLYWOOD SPECIMENS GLUED WITH 10 LABORATORY-FORMULATED FORTIFIED UREA-RESIN GLUES

Glue No.	Type and amount of fortifier		Average joint strengths and percentages of wood failure[1]							
	Melamine resin	Resorcinol	Continuous exposure: to 158° F., 20 percent relative humidity		Continuous exposure: to 80° F., 97 percent relative humidity		97-30 percent relative humidity cycle at 80° F.		90-30 percent relative humidity cycle at 80° F.	
			Tested dry[2]	Tested wet[3]	Tested dry[2]	Tested wet[3]	Tested dry[2]	Tested wet[3]	Tested dry[2]	Tested wet[3]
	Percent	Percent								
1			133-0	114-2	228-41	180-48	245-2	215-6	291-4	257-12
2		20	266-0	249-38	256-3	245-10	291-6	298-8	377-17	347-60
3		40	236-21	274-64	191-82	171-43	281-5	289-7	324-12	336-24
4		60	262-66	271-98	190-4	182-21	298-10	306-8	378-20	360-52
5		80	267-39	272-100	272-8	265-5	348-19	334-8	411-76	352-90
6	100		301-100	324-100	295-65	266-62	401-82	389-91	421-63	400-100
7		10	179-3	210-3	161-81	198-82	227-2	250-2	342-13	381-47
8		20	200-0	307-100	307-84	268-53	303-4	361-17	364-25	428-66
9		40	184-1	298-97	266-100	233-100	338-31	441-79	400-63	479-97
10		60	172-1	277-100	232-100	270-100	384-94	451-100	408-97	478-100

[1] The first value is the average joint strength in pounds per square inch; the second value is the average estimated percentage of wood failure. Each value is the average for 5 specimens

[2] Tested dry after removal from the exposure except that specimens from the 158° F. condition were cooled to room temperature before testing.

[3] Tested wet after 48 hours of immersion in water at room temperature following removal from exposure.

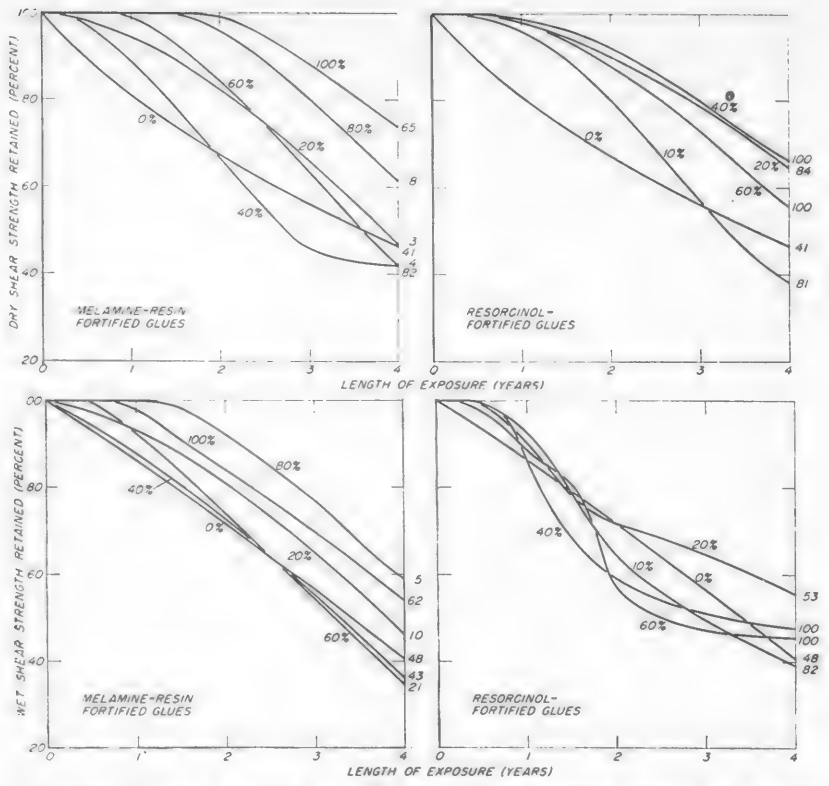

Figure 2.—Effect of exposure at 80° F. and 97 percent relative humidity on the shear strength of yellow birth plywood joints made with urea-resin glues containing various proportions of fortifier. (Number at end of each curve is the average percentage of wood failure observed in the specimens tested at 4 years.)

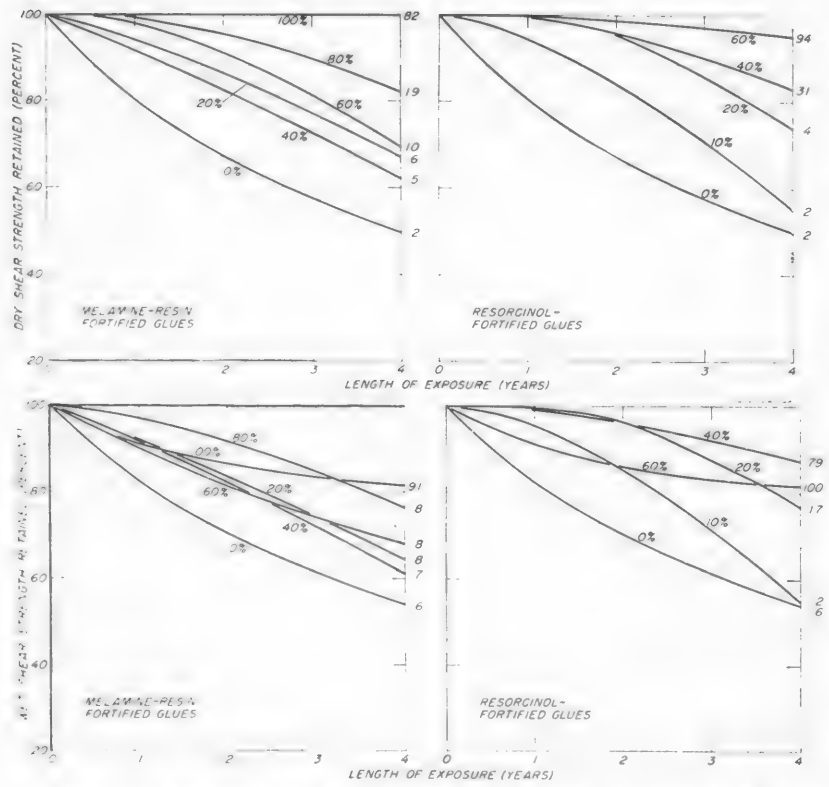

Figure 3.—Effect of exposure to a repeating cycle consisting of 2 weeks at 97 percent relative humidity followed by 2 weeks at 30 percent relative humidity, both at 80° F., on the shear strength of yellow birch plywood joints made with urea-resin glues containing various proportions of fortifier. (Number at end of each curve is the average percentage of wood failure observed in the specimens tested at 4 years.)

creases beyond this are not in direct proportion to the greater amounts of fortifier present in the glue.

Incorporation of 10 percent resorcinol with paraformaldehyde (glue 7) increased the joint performance over that of the straight urea resin in this exposure. In the dry tests, larger proportions of resorcinol had only slight advantages over the 10 percent formulation. Differences between 10, 20, 40, and 60 percent resorcinol were not of great significance, and all formulations showed almost complete glue failure in dry tests after 4 years in this exposure. In wet tests after 4 years in this exposure, the 10 percent resorcinol formulation gave lower wood failures and lower strengths than did those with higher proportions of resorcinol, although the 10 percent formulation was distinctly superior to the straight urea-resin glue (glue 1). The differences between 20, 40, and 60 percent resorcinol (glues 8, 9, and 10) in the wet tests are probably not significant since high wood failures throughout the period of exposure again represent effects of the exposure on the wood rather than on the glue.

Results of dry tests after this high-temperature exposure, therefore, tended to indicate a superiority of the melamine-resin fortified glues over those containing resorcinol. High percentages of melamine resin (glues 4 and 5) tended to approach fairly closely the straight melamine resin (glue 6) in durability in this exposure but did not equal it. The differences between these two fortifiers were slight in wet tests after exposure.

Exposure to Continuous High Humidity: Joints made with the melamine-resin fortified glues (glues 2–5) showed progressive decreases in both strength and wood failures in this exposure (fig. 2). However, no consistent relationships developed between the rate of decrease in strength and the percentages of melamine resin. Differences in actual strength and wood-failure values for these different glues in dry and wet tests after 4 years of exposure were not great, as indicated in table 4. The 20 percent melamine-resin formulation (glue 2) showed somewhat higher joint strengths than did the 40 and 60 percent fortifications. However, higher wood failures in the 40 percent formulation (table 4) suggest that the lower strength may have been influenced by greater effects on the wood rather than on the glue. Considering both strength and wood-failure values, the straight melamine resin (glue 6) was somewhat more durable than were any of the fortified glues (glues 2–5).

Joints made with the resorcinol-fortified glues (glues 7–10) generally

broke with consistently high percentages of wood failure, indicating a possible damage to the wood in this high-humidity condition rather than to the glue. These results tended to indicate that resorcinol-fortified glues are less severely damaged themselves than were the melamine-resin fortified glues. The resorcinol-modified glues appeared to be similar in performance to the straight melamine resin (glue 6) in this exposure.

In general, fortifiers of the types studied seemed to have much less effect on the performance of urea resins in this high humidity exposure than they did in the high-temperature exposure.

Repeated Cyclic Exposure to 97 and 30 Percent Relative Humidity at 80° F.: The performance of the melamine-resin fortified series in this cyclic exposure was roughly in proportion to the percentage of fortifier (fig. 3). Twenty percent melamine resin had a distinct advantage in dry and wet tests over straight urea resin. Differences between 20, 40, and 60 percent melamine resin were slight. Eighty percent melamine resin was, in turn, somewhat higher than the 20, 40, and 60 percent series, and straight melamine resin was still better than the 80 percent fortification by about the same amount. The straight melamine resin (glue 6) was distinctly better, based on both joint strength and wood-failure values, than any of the urea-melamine resin series (glues 2–5).

Performances of the resorcinol-fortified series (glues 7–10) were also in proportion to the percentages of fortifier and were generally better than those of the glues containing similar proportions of melamine-resin fortifier.

Percentages of strength retained by the 60 percent resorcinol glue (glue 10) in the wet tests are shown to be lower than for 20 percent glue for a time, and lower than for the 40 percent resorcinol throughout the exposure. This was largely because the initial wet strength of the 60 percent glue was unusually high (558 p.s.i.), and because 95 percent and higher wood failures were observed with this glue in wet tests throughout this exposure, indicating that the glue was more durable than the wood in this exposure. As indicated in table 4, the performance of the 60 percent resorcinol-fortified glue was as good as that of the straight melamine resin (glue 6) with nearly complete wood failures being noted, and distinctly better than that of the 80 percent melamine-resin formulation (glue 5).

Repeated Cyclic Exposure to 90 and 30 Percent Relative Humidity at 80° F.: This exposure was the mildest included in this study. The performances of both the melamine-resin and resorcinol-fortified series in the dry tests were generally in proportion to the amounts of fortifier. There was a slight reversal in the 20 and 40 percent melamine-resin formulations in the dry tests, as had been also noted in some of the previous exposures. The differences between the two were not large. Even the least proportion of fortifier, of either type, clearly improved glue joint durability in this exposure.

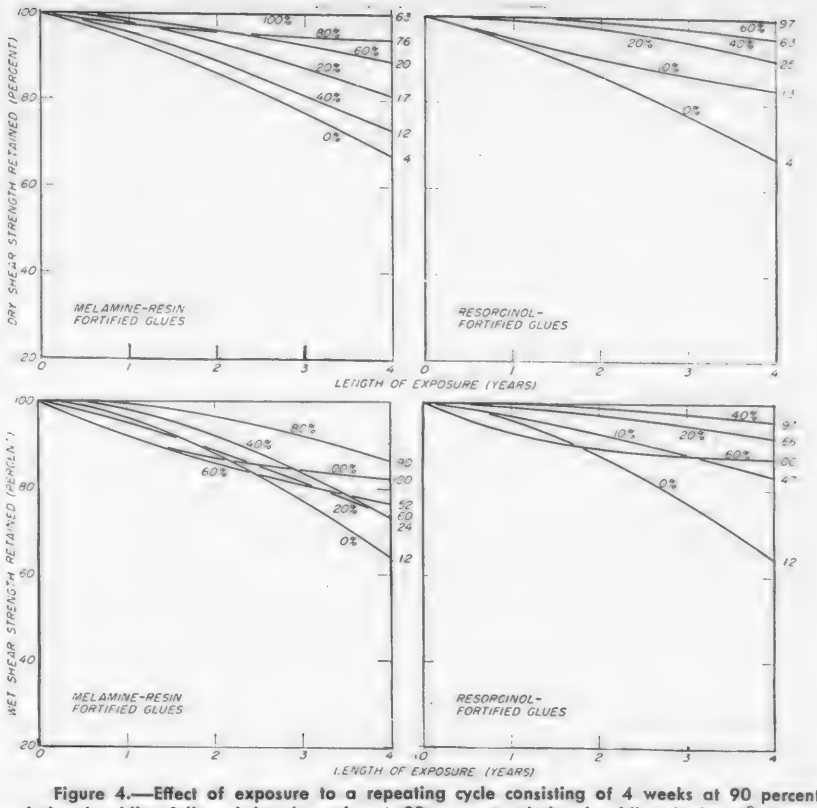

Figure 4.—Effect of exposure to a repeating cycle consisting of 4 weeks at 90 percent relative humidity followed by 4 weeks at 30 percent relative humidity, both 80° F., on the shear strength of yellow birch plywood joints made with urea-resin glues containing various proportions of fortifier. (Number at end of each curve is the average percentage of wood failure observed in the specimens tested at 4 years.)

Definite relationships between performance in wet tests and percentages of fortifier were not so clear cut. The 100 percent melamine resin (glue 6) showed lower percentages of wet strength retention than did 80 percent melamine-resin glue. Both 80 and 100 percent formulations showed 90 percent or higher wood failures in wet tests throughout this exposure; therefore, again the trends for these glues were more determined by the wood than by the glues. This situation was also responsible for the lower percentages of strength retention of the 60 percent resorcinol formulation in wet tests compared to the 20 and 40 percent resorcinol formulations.

In this exposure, the 40 and 60 percent resorcinol-fortified glues (glues 8-10) were equivalent or superior to the 80 percent melamine-resin formulation and were nearly as good as the straight melamine-resin glue. Ten percent resorcinol (glue 7) was a distinct improvement over the unfortified urea resin, and 20 percent resorcinol was, in turn, somewhat better than 10 percent.

Exposure to Weather: After 4 years of exterior weathering of plywood panels near Madison, without paint or mechanical protection, only the yellow birch panels made with the straight urea-resin glue (glue 1) showed any visible delamination. At that time, the average delamination of the three-ply, 3/16-inch yellow birch panels was 4.0 percent of the entire joint areas, and it was 2.7 percent for the five-ply, 5/8-inch birch panels. None of the yellow-poplar or Douglas–fir panels showed any delamination with this urea-resin glue. No joint shear tests were made after this exposure. These fence exposures are being continued, since it is still too early to show any definite advantages of the different amounts and types of fortifiers under exterior weathering.

Conclusions

Incorporation of at least 20 percent melamine resin or 10 percent resorcinol with added paraformaldehyde was shown to have distinct value in improving the resistance of the bonds in yellow birch plywood made with a conventional hot-press urea-resin glue to con-

tinuous exposure at 158° F. and 20 percent relative humidity, and under repeating cycles of high and low humidity at 80° F. Such fortification was least effective in a continuous exposure at 80° F. and 97 percent relative humidity.

Generally, the improvement with either melamine resin or resorcinol fortifier was in direct proportion to the amount of fortifier added, with the most significant improvement being noted between the straight urea resin and the lowest amounts of fortifier of each type. Melamine-resin fortification seemed to have some advantage over resorcinol in the continuous high-temperature exposure, while resorcinol fortification had an advantage over melamine resin in the cyclic high-low humidity exposures. The straight melamine-resin glue was definitely more durable than any of the fortified urea-resin formulations in the high-temperature exposure. Higher proportions of both fortifiers tended to approach the performance of straight melamine resin quite closely in the continuous and cyclic high-humidity conditions.

On the basis of present data, it is not possible readily to determine the optimum proportion of either melamine resin or of resorcinol to use in urea-resin glues for general improvement of durability under a variety of conditions. This question will probably have to be answered by resolving the relative importances of durability and economics for special applications.

Strength Properties of Paper-Covered Veneer From True Fir and White-Speck Douglas Fir[1]

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Evaluation of the strength and related properties of white-speck Douglas fir, true fir, and ponderosa pine apple box shook. Results of testing 820 specimens analyzed statistically.

Objective and Scope

THE OBJECTIVE of this study was to compare the strength and related properties of paper-covered veneer from white-speck Douglas fir with sound true fir veneer and ponderosa pine apple-box shook. The types of paper-covered veneers investigated included 1/8-inch Douglas fir *(Pseudotsuga menziesii* Mirb., Franco) containing light, medium, and heavy amounts of white speck or honeycomb, 3/16-inch Douglas fir with a medium amount of white speck, and 1/12-inch and 1/8-inch defect-free true fir (*Abies* sp.). Ponderosa pine 5/16-inch apple-box shook was used as an additional comparative material in some of the tests. The material was tested after part of it had reached an equilibrium moisture content in a high humidity of 85 per cent and the remaining portion in an intermediate humidity of 65 per cent. After conditioning, the specimens were tested for puncture resistance, nail-holding ability (direct and lateral withdrawal), stiffness and bending strength. The test results were analyzed statistically.

Experimental Procedure

In order to evaluate the strength and related properties of paper-covered veneer, 820 test specimens of both sound and white-speck material were tested at the Oregon Forest Products Laboratory. The experimental procedure is divided into: (1) description of the test materials, (2) conditioning of the test specimens and (3) testing.

Description of Test Materials: Test materials representing six types of paper-covered veneer, and ponderosa pine 5/16-inch apple-box shook were obtained. The paper overlays were either 50-pound kraft paper or 42-pound liner board. The Douglas fir veneers were bonded on both sides with the 42-pound liner board while the true fir veneers were covered with 50-pound kraft paper on one side and 42-pound liner board on the other. The paper-covered material included 1/8- and 3/16-inch Douglas fir veneer which contained white speck and honeycomb, and 1/12- and 1/8-inch sound true fir veneer. In the designations of the paper-covered veneers, the dimensions 1/12, 1/8, and 3/16 inch refer to the thickness of the veneer only.

The paper-covered test materials were manufactured by two different processes. In the first process, all of the Douglas fir veneer was bonded to the paper overlay while at the green moisture content, and the complete item was then dried. This method of manufacture is known as the Craveneer process which was developed by chemists and engineers of the Chicago Mill and Lumber Co., Chicago, Illinois. In this process, in which the kraft paper is applied directly to green veneer, the veneer becomes distended and checked after drying. Therefore, it is likely that a panel material made by some other process which did not involve distending the veneer might be denser and stronger for a given thickness than the material made by the Craveneer process; consequently, care should be taken in applying the test results from this study to other veneer-paper panel materials. In the second process, the true fir veneers were dried prior to the bonding of the paper covering.

The paper-covered 1/8-inch Douglas fir veneer was separated into three classes according to the amount of white speck and honeycomb. The classification was empirical in which class I had a

TEST MATERIAL DESCRIPTION

Species	Material	Thickness Inch	White speck or honeycomb	Overlay		Symbol used in tables
				Face	Back	
Ponderosa pine	Box shook	5/16	None	None	None	Pine
Douglas fir	Veneer	3/16	Medium	42-pound liner board	42-pound liner board	3/16 DF
Douglas fir	Veneer	1/8	Light	42-pound liner board	42-pound liner board	1/8 DF I
Douglas fir	Veneer	1/8	Medium	42-pound liner board	42-pound liner board	1/8 DF I
Douglas fir	Veneer	1/8	Heavy	42-pound liner board	42-pound liner board	1/8 DF II
True fir	Veneer	1/12	None	42-pound liner board	50-pound kraft paper	1/12 TF
True fir	Veneer	1/8	None	42-pound liner board	50-pound kraft paper	1/8 TF

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light amount of white speck, class II a medium amount of white speck and honeycomb, and class III a large amount of honeycomb (Figure 1).[3] The 3/16-inch Douglas fir paper-covered veneer had a medium amount of honeycomb, making it comparable to 1/8-inch class II except for the additional thickness. In addition to the Douglas fir veneers, the comparative test materials included 1/12-inch and 1/8-inch sound, paper-covered true fir veneer and 5/16-inch pine apple-box shook. Only this one thickness of pine shook was used as a test material, so for the remainder of the report it will be designated simply as pine shook. The true fir product was selected since the 1/12-inch material is a commercial box material being utilized in a one-piece, wrap-around-type box. The pine shook was evaluated in all the tests with the exception of puncture resistance. The pine offered a resistance above the capacity of the G.E. puncture tester.

For each of the four tests, the test specimens were selected from the material completely at random by use of a table of random numbers.

Conditioning: After the test specimens had been cut to size, they were brought to an equilibrium moisture content in one of the two conditioning rooms. One room was maintained at approximately 85 per cent relative humidity and 80 deg F. The second room was controlled at approximately 65 per cent relative humidity and 70 deg F.

The test specimens assigned to the puncture-resistance and bending-strength tests were immediately divided between the two conditioning rooms and were tested after they had reached an equilibrium moisture content.

All of the specimens assigned to the nail-holding tests were permitted first to reach an equilibrium moisture content at the lower humidity level. Six 4-penny cement-coated nails were then driven through the veneer into the end-grain of the pine box ends that had also reached equilibrium in the 65 per cent humidity room. After joint fabrication, half of the specimens for each nailing test was placed in the 85 per cent relative humidity room and permitted to reach an equilibrium moisture content. The other half remained in the 65 per cent relative humidity room.

Testing: All of the materials were tested to determine lateral nail-withdrawal resistance, direct nail-withdrawal resistance, modulus of rupture, and modulus of elasticity. The 3/16-inch Douglas fir veneer and the pine shook were not tested for puncture resistance since they exceeded the capacity of the G. E. puncture tester. All the remaining materials were tested for puncture resistance (Figure 2).

The static bending tests were performed by using a six-inch span and a head speed of 0.50 inch per minute. The longitudinal direction of the veneer was parallel to the span.

The tests for lateral nail-withdrawal resistance and direct nail-withdrawal resistance were performed with a 20,000-pound Tinius Olsen Universal Testing Machine and a special clamp developed at the Laboratory. In the nail test for direct withdrawal (Figure 3), the paper-covered veneer was fastened to the stationary crosshead while the pine box end was clamped to the movable crosshead. As the movable crosshead was lowered, the test specimen was in tension, and the six 4-penny cement-coated nails were either pulled through the veneer or the nail shanks withdrew from the pine box end. The lateral nail-withdrawal resistance was measured with the same apparatus (Figure 4), but the pine box end was fastened to the stationary crosshead and the paper-covered veneer was clamped to the movable crosshead. When the movable crosshead was lowered, the nails either pulled through the end of the veneer or withdrew from the pine box end.

Statistical Analysis

To aid in detecting significant differences among the various materials, an analysis of variance was employed to make comparisons at each humidity level. In addition to these analyses, the

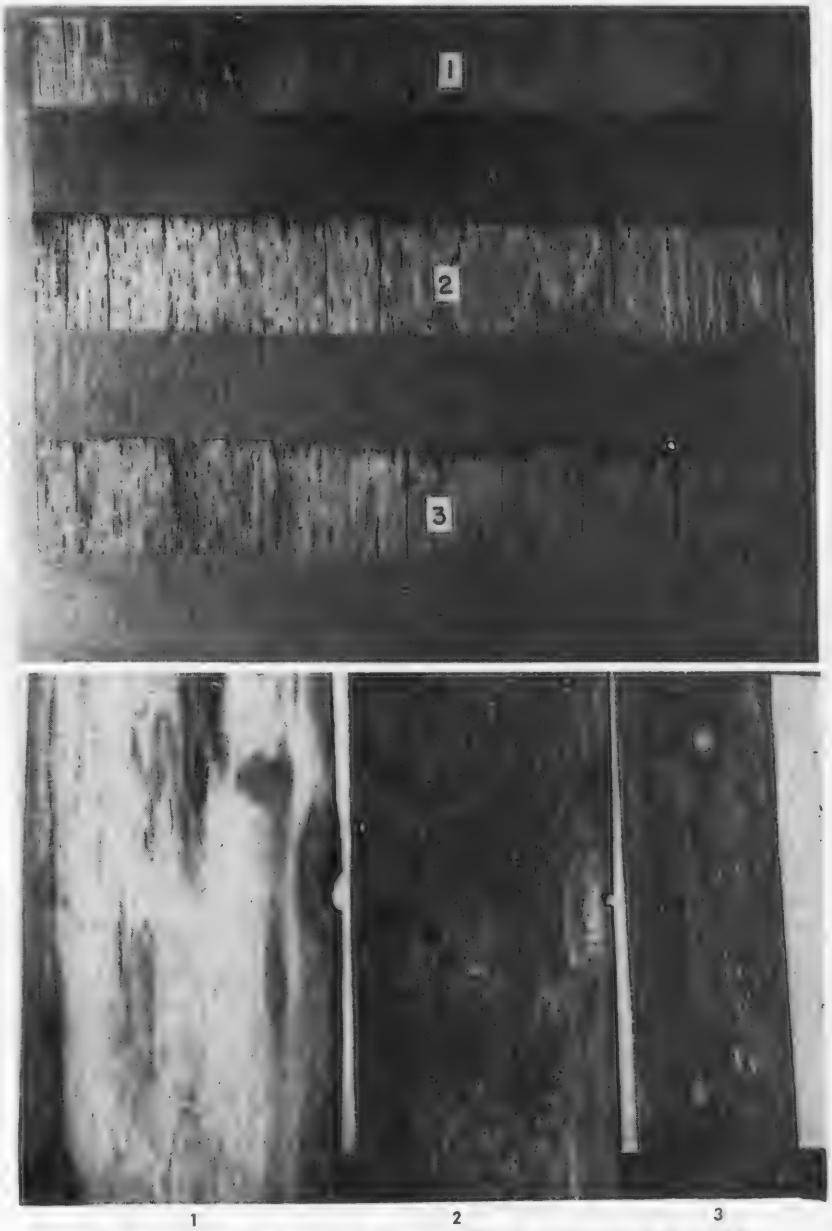

Figure 1.—The three empirical classes of *Fomes pini*-infected Douglas-fir veneer, shown with and without a Kraft paper overlay.

[3] Stillinger, J. R. "Some Strength and Related Properties of Old-growth Douglas-fir Decayed by *Fomes pini*." April 1951. Reprint from ASTM *Bulletin*, No. 173.

Figure 2.—Puncture tester, with specimens before and after testing.

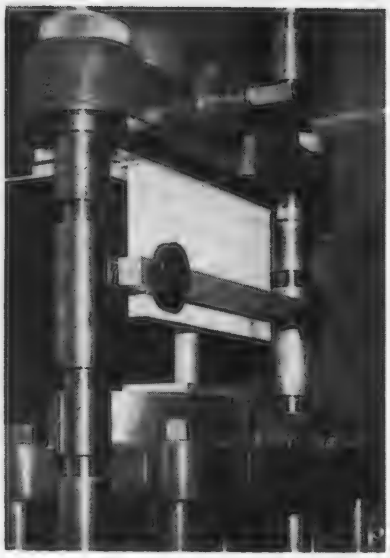

Figure 3.—Specimen mounted for testing of direct nail-withdrawal resistance.

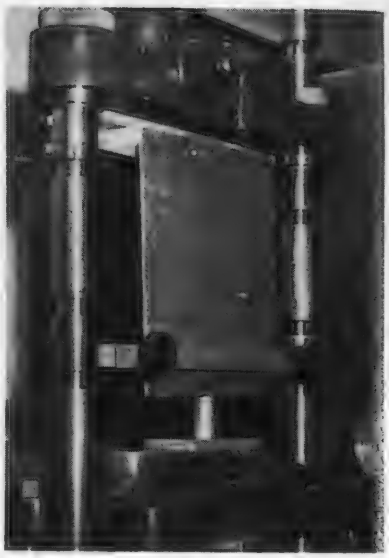

Figure 4.—Specimen mounted for testing of lateral nail-withdrawal resistance.

data from testing each of the five strength properties were pooled, and a separate analysis of variance was conducted to obtain an average ranking of the materials for both humidities. A significance level of 95 per cent was used throughout the statistical analysis. If a significant difference was detected by the analysis of variance, the individual test means were compared by J. W. Tukey's method using the least significant difference and the test of the extreme mean.[4] The results of the analysis of variance are summarized in Tables 8, 9 and 10.

Results and Discussion

Each property will be discussed separately. A tabular method of presentation has been used with a general evaluation following. Two separate tables present the test results for each property. The first table gives comparative values for each humidity level used in testing. If a material is known to be utilized at one of these humidities, then the results of the first table may be directly employed. However, if a material may be subjected to either or both humidities, the second table, which gives average values for both humidities, should be consulted. The materials were ranked from the results of the statistical analysis. The strength values given were averages of all the different materials with the same rank.

Puncture resistance: The results of the G. E. puncture test are summarized in Table 1 and Table 1A.

The data in Table 1 show that material with a light amount of white speck (I) was more resistant to puncture at both humidity levels while there was no difference between the material with a medium (II) and a heavy (III) amount of white speck and honeycomb. All of the Douglas fir veneers were higher in puncture resistance than was the commercial 1/12-inch true fir product.

The ranking in Table 1A indicates that when the puncture resistance of the test materials for both humidities were averaged, the 1/8 DF II Douglas fir product had a higher puncture resistance than did the material with a large amount of honeycomb.[5]

Both the 3/16-inch Douglas fir material and the pine shook exceeded the 1600-in.-oz-per-inch tear capacity of the

[4] Tukey, J. W. "Comparing Individual Means in the Analysis of Variance." June 1949. *Biometrics*, American Statistical Association, Vol. 5, No. 2.

[5] In Table 1, the 1/8 DF II and 1/8 DF III materials are ranked second for both the 65 per cent humidity level and the 85 per cent humidity level. It might be expected that a ranking based on the values for both humidities would place them in the same rank, but Table 1A assigns the 1/8 DF II material to the second rank while the 1/8 DF III product is in the third rank. This anomaly may be explained if the derivation of the tables is analyzed.

Table 1A presents the results of the analysis of variance for the raw data at both humidity levels, therefore, the full effect of any interaction between the materials and humidity would influence the ranking in this table. Another factor that influenced the ranking in Table 1A was the increase in sample size. When the test values for both humidities were utilized in one analysis of variance, the size of sample was doubled. This produced a smaller error mean square, so the values of the least significant difference and the extreme mean were reduced.

Table 1A.—AVERAGE PUNCTURE RESISTANCE FOR BOTH HUMIDITIES

Material	Puncture resistance*	Rank
1/8 DF I	963	1
1/8 DF II	808	2
1/8 DF III 1/8 TF	742	3
1/12 TF	595	4

*Inch-ounces per inch of tear (average values for each rank).

Table 1.—PUNCTURE RESISTANCE FOR INDIVIDUAL HUMIDITIES

Relative humidity and temperature in conditioning rooms

65 per cent humidity, 70 deg F			85 per cent humidity, 80 deg F		
Material	Puncture resistance*	Rank	Material	Puncture resistance*	Rank
1/8 DF I**	896	1	1/8 DF I	1031	1
1/8 DF II 1/8 DF III 1/8 TF	741	2	1/8 DF II 1/8 DF III	814	2
1/12 TF	556	3	1/8 TF	734	3
			1/12 TF	634	4

*Inch-ounces per inch of tear (average values for each rank).
**See table of Test Material Description, page 56, for symbols used to describe test materials.

Table 2.—LATERAL NAIL-WITHDRAWAL RESISTANCE FOR INDIVIDUAL HUMIDITIES

Relative humidity and temperature in conditioning rooms

65 per cent humidity, 70 deg F			85 per cent humidity, 80 deg F		
Material	Resistance Lb/nail*	Rank	Material	Resistance Lb/nail*	Rank
Pine 3/16 DF 1/8 DF I 1/8 DF II 1/8 DF III 1/8 TF 1/12 TF	78	1	1/8 TF	67	1
			3/16 DF 1/8 DF I 1/8 DF II 1/8 DF III 1/12 TF	51	2
			Pine	42	3

*Average values for each rank.

G.E. puncture tester, and were not included in this test.

Lateral Nail-withdrawal Resistance: The results of this nail test are presented in Table 2 and Table 2A.

All the materials were equal in lateral nail-withdrawal resistance at the lower humidity level, and the majority of the failures at maximum load were caused by the nails withdrawing from the pine box end rather than by pulling through the material. At the higher humidity, all the paper-covered veneers were more resistant than was the pine box shook.

Table 2A.—AVERAGE LATERAL NAIL-WITHDRAWAL RESISTANCE FOR BOTH HUMIDITIES

Material	Resistance Lb/nail*	Rank
Pine 3/16 DF 1/8 DF I 1/8 DF II 1/8 DF III 1/12 TF 1/8 TF	65	1

*Average values for each rank.

Although the pine shook was lower in lateral nail-withdrawal resistance at the higher humidity, the average values for both humidities showed no differences among the products.

It should be pointed out that the test apparatus described and illustrated in Figures 3 and 4 actually did not measure the direct nail-withdrawal resistance and the lateral nail-withdrawal resistance of the paper-covered materials. The tests measured either the resistance to nail withdrawal of the pine box end (end-grain nailing) or the resistance to nailhead pull-through of the panel material, depending upon the type of failure.

Direct Nail-withdrawal Resistance: The comparison of materials for this test is given in Table 3 and Table 3A.

At 65 per cent humidity, the thicker materials had higher resistance values than did the 1/8-inch or 1/12-inch paper-covered veneers. At point of failure the nails had developed greater resistance in thicker materials. This was indicated in the tests of the thicker materials by the nails withdrawing from the pine ends, while the nail heads exhibited a tendency to pull through the thinner products. This situation did not exist at the high humidity, for the thinner products had withdrawal resistance equal to or greater than that of the thicker materials.

Table 3A.—AVERAGE DIRECT NAIL-WITHDRAWAL RESISTANCE FOR BOTH HUMIDITIES

Material	Resistance Lb/nail*	Rank
Pine 3/16 DF 1/8 DF I 1/8 DF II 1/8 DF III 1/12 TF 1/8 TF	36	1

*Average values for each rank.

Table 3.—DIRECT NAIL-WITHDRAWAL RESISTANCE FOR INDIVIDUAL HUMIDITIES

Relative humidity and temperature in conditioning rooms

65 per cent humidity, 70 deg F			85 per cent humidity, 80 deg F		
Material	Resistance Lb/nail*	Rank	Material	Resistance Lb/nail*	Rank
3/16 DF	53	1	1/8 TF	32	1
Pine 1/8 DF I 1/8 DF II 1/8 DF III 1/8 TF 1/12 TF	51 43	2 3	Pine 3/16 DF 1/8 DF I 1/8 DF II 1/8 DF III 1/12 TF	26	2

*Average values for each rank.

Table 4.—MODULUS OF RUPTURE FOR INDIVIDUAL HUMIDITIES

Relative humidity and temperature in the conditioning rooms

65 per cent humidity, 70 deg F			85 per cent humidity, 80 deg F		
Material	Modulus of rupture* Psi**	Rank	Material	Modulus of rupture* PSI**	Rank
Pine 3/16 DF 1/8 DF I 1/8 DF II 1/8 TF	9,650	1	Pine	6,790	1
1/8 DF III 1/12 TF	6,520	2	3/16 DF 1/8 DF I 1/8 DF II 1/8 TF	5,530	2
			1/12 TF	4,150	3
			1/8 DF III	3,590	4

*Based on dimensions at time of test, including paper
**Average values for each rank.

Table 3A indicates that all the materials had equal average resistance to direct nail withdrawal when averaged for both humidity conditions.

Modulus of Rupture: From the maximum loads obtained in the static bending tests, the modulus of rupture was determined for each material. The results are given in Table 4.

The No. III grade of Douglas fir material was lower at both humidities in modulus of rupture than were any of the other grades of Douglas fir paper-covered veneer. The 1/12-inch true fir product was lower in modulus of rupture at both humidities than the 1/8-inch true fir material; this was probably because of the increased ratio of paper to veneer on the thinner product.

Table 4A for both humidities separates the Douglas fir veneer with a large amount of honeycomb as having the lowest modulus of rupture, but the values for the other 1/8- and 3/16-inch paper-covered veneers were equal to the modulus of rupture of the pine shook.

All materials having the same thickness and modulus of rupture would be capable of resisting the same total load under the same loading conditions. However, all the paper-covered veneers were thinner than the pine box shook, so a further evaluation of the material was made using the pine box shook as the criterion. For a given type of loading, the maximum load for any span and width is proportional to the modulus of rupture and the square of the thickness. Table 5 gives the comparative strength for all the materials at the lower humidity level based on the maximum load.

Table 4A.—AVERAGE MODULUS OF RUPTURE FOR BOTH HUMIDITIES

Material	Modulus of rupture Psi*	Rank
Pine 3/16 DF 1/8 DF I 1/8 DF II 1/8 TF	7,715	1
1/12 TF	5,251	2
1/8 DF III	5,133	3

*Average values for each rank.

Table 5.—COMPARATIVE STRENGTH AT 65 PER CENT HUMIDITY LEVEL

Material	Modulus of rupture Psi	Average thickness* Inch	Comparative strength
Pine	9,650	0.290	1.00
3/16 DF	9,650	.224	0.60
1/8 DF I	9,650	.152	.28
1/8 DF II	9,650	.152	.28
1/8 TF	9,650	.152	.28
1/8 DF III	6,520	.152	.19
1/12 TF	6,520	.107	.09

*Dimensions at time of test, including paper.

Table 5 indicates that for any given method of loading the 3/16-inch Douglas fir product would develop approximately 60 per cent of the maximum pine shook load. However, this same material would develop about twice the maximum load of the Douglas fir I and II product, and 6 times the maximum load of the 1/12-inch paper-covered, true fir veneer.

Modulus of Elasticity: From the load-deflection curves, a load and deflection were taken within the proportional limit of the material and the modulus of elasticity was calculated. Tables 6 and 6A give test values for modulus of elasticity.

This table indicates that at each humidity the Douglas fir paper-covered veneer with much honeycomb, and the

1/12-inch true fir veneer, were lower in stiffness values than were the other products.

Table 6A.—AVERAGE MODULUS OF ELASTICITY FOR BOTH HUMIDITIES

Material	Modulus of elasticity* Psi**	Rank
Pine 3/16 DF 1/8 DF I 1/8 DF II 1/8 TF	922,100	1
1/8 DF III 1/12 TF	636,100	2

*Based on dimensions at time of test, including paper.
**Average values for each rank.

The materials presented in Table 6A had the same ranking as the 85 per cent humidity section of Table 6, although the average modulus of elasticity for both humidities was approximately 150,000 psi greater.

Materials of equal length and width with the same modulus of elasticity and thickness would deflect a like amount under the same load conditions. The amount of deflection under a given load condition is inversely proportional to the modulus of elasticity and the third power of the thickness in material of the same length and width. For a more practical comparison the materials are rated in Table 7 according to their deflection for a given load condition compared with the pine shook.

For any given load condition, the 3/16-inch Douglas fir material would deflect over twice as much as the pine shook, while the 1/8-inch Douglas fir I and II products deflected about seven times as much as the pine shook.

No attempt was made to determine which of the materials was suitable for a specific use. It should be pointed out that the 1/12-inch true-fir product was not utilized in a box employing separate sides, top, and bottom but was used in a one-piece, wrap-around type of box which increased the rigidity and strength of the finished product.

Table 7.—COMPARATIVE DEFLECTION AT THE 65 PER CENT HUMIDITY LEVEL

Material	Modulus of elasticity Psi	Average thickness* Inch	Comparative deflection
Pine	1,067,500	0.290	1.00
3/16 DF	1,067,500	.224	2.20
1/8 DF I	1,067,500	.152	7.00
1/8 DF II	1,067,500	.152	7.00
1/8 TF	1,067,500	.152	7.00
1/8 DF III	848,400	.152	8.70
1/12 TF	724,900	.107	29.30

*Dimensions at time of test, including paper.

Table 6.—MODULUS OF ELASTICITY FOR INDIVIDUAL HUMIDITIES

Relative humidity and temperature in the conditioning rooms

65 per cent humidity, 70 deg F			85 per cent humidity, 80 deg F		
Material	Modulus of elasticity* Psi**	Rank	Material	Modulus of elasticity* Psi**	Rank
Pine 3/16 DF 1/8 DF I 1/8 DF II 1/8 TF	1,067,500	1	Pine 3/16 DF 1/8 DF I 1/8 DF II 1/8 TF	776,700	1
1/8 DF III	848,400	2	1/8 DF III 1/12 TF	485,400	2
1/12 TF	724,900	3			

*Based on dimensions at time of test, including paper.
**Average values for each rank.

Table 8.—ANALYSIS OF VARIANCE OF TEST DATA (65 Per Cent Relative Humidity, 70 Deg F)

Property analyzed	Source of variation	Degrees of freedom	F	Remarks*
Puncture resistance	Material	4	25.8	S
	Error	195		
Lateral nail-withdrawal resistance	Material	6	1.77	N.S.
	Error	63		
Direct nail-withdrawal resistance	Material	6	4.67	S
	Error	63		
Modulus of rupture	Material	6	10.03	S
	Error	63		
Moduius of elasticity	Material	6	6.81	S
	Error	63		

*"S" indicates a significant difference with a significance level of 95 per cent. "N.S." indicates no significant difference.

Table 9.—ANALYSIS OF VARIANCE OF TEST DATA (85 Per Cent Relative Humidity, 80 Deg F)

Property analyzed	Source of variation	Degrees of freedom	F	Remarks*
Puncture resistance	Material	4	43.65	S
	Error	195		
Lateral nail-withdrawal resistance	Material	6	9.96	S
	Error	63		
Direct nail-withdrawal resistance	Material	6	3.8	S
	Error	63		
Modulus of rupture	Material	6	7.80	S
	Error	63		
Modulus of elasticity	Material	6	9.15	S
	Error	63		

*"S" indicates a significant difference with a significance level of 95 per cent. "N.S." indicates no significant difference.

Table 10.—ANALYSIS OF VARIANCE OF POOLED TEST DATA (Both Humidities and Temperatures)

Property analyzed	Source of variation	Degrees of freedom	F	Remarks*
Puncture resistance	Material	4	61.3	S
	Error	395		
Lateral nail-withdrawal resistance	Material	6	1.64	N.S.
	Error	133		
Direct nail-wthdrawal resistance	Material	6	1.18	N.S.
	Error	133		
Modulus of rupture	Material	6	6.84	S
	Error	133		
Modulus of elasticity	Material	6	11.2	S
	Error	133		

*"S" indicates a significant difference with a significance level of 95 per cent. "N.S." indicates no significant difference.

Analysis of Variance: Tables 8, 9, and 10 show the results of the analysis of variance for the two conditioning rooms.

Summary

The results of the tests indicated that with the exception of the 1/8-inch Douglas fir with a large amount of honeycomb, and the sound 1/12-inch true fir material, all materials tested were equal in modulus of rupture and modulus of elasticity. The 1/8-inch Douglas fir veneer with a large amount of honeycomb was equal in strength to the 1/12-inch sound white fir product (both of these materials were approximately equal to the other 1/8-inch paper-covered veneers in nail-holding ability, even though lower in bending strength.) All of the paper-covered veneers gave the same average results as the pine shook in both nail-holding tests.

No direct comparison can be made among all the materials in puncture resistance because both the pine and 3/16-inch Douglas fir material exceeded the limitations of the testing machine; consequently, both of the thicker materials would be more resistant to puncture than any of the 1/8- or 1/12-inch paper-covered veneers. Of the Douglas fir materials tested, the amount of honeycomb directly influenced the puncture resistance, with the heavily honeycombed Douglas fir having the lowest puncture resistance.

Tests were made on specimens which had undergone extended exposure to 65 per cent relative humidity to simulate ordinary use conditions. Other specimens were tested after exposure to 85 per cent relative humidity to simulate conditions undergone by vegetable shipping crates. In general, most tests gave higher values at the 65 per cent humidity level. However, most materials had greater puncture resistance at 85 per cent relative humidity.

At 65 per cent relative humidity and 70 deg F, with the individual product thickness taken into consideration, it was found that under the same loading conditions the pine shook could take a maximum load approximately 1½ times greater than the 3/16-inch Douglas fir product and would deflect only one half as far. However, when the pine was compared in the same manner with the 1/8-inch Douglas fir material with either light or medium amounts of white speck, the pine could take a maximum load about 4 times greater and would deflect only one-seventh as far.

The Douglas fir veneer with light and medium amounts of white speck gave test values equal to or greater than those of the 1/12-inch true fir product for all properties evaluated. Since this true fir material is commercially utilized in a one-piece, wrap-around type of box, it might be assumed that 1/8-inch Douglas fir paper-covered veneer with light and medium amounts of white speck could be used for a similar product.

The 3/16-inch paper-covered Douglas fir veneer with a medium amount of white speck compared favorably with the pine shook, although the additional thickness of the pine material made it stiffer and stronger. However, for reasonable load and deflection requirements, the 3/16-inch Douglas fir material could probably be used in much the same manner as the pine product.

Acknowledgments

Credit for the instigation and the completion of this work on paper-covered veneer must go largely to the Bohemia Lumber Company, Culp Creek, Oregon, who bore part of the expense of the investigation and also furnished the Douglas fir veneer used in testing.

The Chicago Mill and Lumber Company in Tallulah, Louisiana was very helpful in peeling green Douglas fir veneer and making paper-veneer panels by the Craveneer process for the study material.

Appreciation is expressed to the Milwaukie Box and Veneer Company, Milwaukie, Oregon, who furnished the true fir material tested, and also to the Apple Growers' Association, Hood River, Oregon, who provided the ponderosa pine box shook used as a standard for comparison.

Possibilities of the Glueline-Cleavage Test When Applied to Hardboard[1]

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This paper presents certain evidence and some opinions which indicate to the author that the glueline–cleavage method might be a good test of the gluability of hardboard and to suggest that research be undertaken to prove or disprove this contention.

KNOWLEDGE OF THE STRENGTH of materials is based upon the results of mechanical tests. If methods of test yield inaccurate results or if results are inaccurately interpreted there will be inadequate understanding of these strength properties. In an effort to provide additional information about glue bonds in plywood, research was undertaken by the author, one result of which was the development of a new method of test, the glueline-cleavage test. This test was described in a paper previously published.[2]

A testing machine for glueline-cleavage tests was designed at the Vancouver laboratory of the Forest Products Laboratories of Canada. The machine consists of a wedge, a hydraulic jack to apply the load, and a gauge to read it. The specimen, cut from the sheet to be tested—in this case hardboard—is one inch square. It is placed in the machine and aligned so that the knife edge will bisect it.[3] After a slight pressure has been built up the cleaving force is applied with a single, uniform stroke and the breaking load is read. With some practice an operator can test approximately two specimens per minute.

Glue tests may be required for three rather different purposes:

1. For research
2. For glue specification
3. For production quality control.

Each of these tests has its own special problems, but all have certain common requirements. For research purposes accuracy is probably of most importance. For glue specification purposes one of the most important factors is that the materials bonded shall be strong enough to test the glue. For production testing it is necessary to use the product as manufactured. This imposes restrictions which limit the accuracy of these test results. Due to the relatively large number of tests which must be made for production control, the use of less accurate but more simple test methods may frequently be justified. In general, these remarks have to do with research testing, though some of them will apply equally to the other tests.

One of the first requirements of the ideal test is that it must measure the desired property of the material. It may be necessary to use several tests in order to measure as many different properties of a material. For example, it is common practice to measure such widely different properties as the specific gravity, modulus of rupture, fibre strength at elastic limit, modulus of elasticity, tensile strength and compressive strength.

In the case of hardboard gluability it may be desirable to test the capacity of a glue to resist shearing forces in the plane of the bond. The block shear and tension shear tests are well known methods used for this purpose with wood and they could no doubt be adapted to hardboard.

A second property of the bond which it may be desirable to measure is its strength in tension perpendicular to the glue line. Since plywood and hardboard are relatively weak in tension perpendicular to the surface, it will frequently happen that this is the critical strength property. That is, when conditions are right to set up shearing stresses in the glue lines of large flat

[1] Present at the Hardboard Division, FPRS Pacific Northwest Section Meeting, Aberdeen, Washington, May 17, 1954.

[2] Northcott, P. L., The Development of the Glueline-Cleavage Test, Journal of the Forest Products Research Society, Vol. II, No. 5, Dec. 1952. Madison, Wisconsin.

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[3] Figures 1 and 1A of "The Development of the Glueline-Cleavage Test" show the machine with a specimen in position for testing.

sheets, the component of stress acting perpendicular to the surface may be sufficient to cause failure of the sheet material in tension perpendicular to the surface rather than in shear.

Some requirements of the ideal test are listed in Figure 1. It should be understood that this rating is the author's and that it is based upon experience with wood and plywood rather than with hardboard. In the various columns are listed the block shear, tension shear, tension normal, cross-lapped, glueline cleavage, and percent wood failure methods.

1) The first requirement listed is *reproducibility* or *accuracy*. Block shear, tension shear, and glueline-cleavage have the highest rating to which has been given the number 1. This is for specimens of the production control type where it is not possible to take advantage of the greater accuracy provided by the glueline-cleavage test when used with specially prepared specimens. The tension normal and cross-lapped specimens have been given a rating of 2, and the percent wood failure method a rating of 4.

2) The second requirement is that the results of the test be expressed in universally acceptable, unequivocal terms, such as force in pounds or stress in p.s.i. All of the mechanical methods have been rated as 1; the percent wood failure method as 3.

3) The third requirement listed is *simplicity of test specimen design*. The simplest, especially when dealing with the gluability of sheet materials such as hardboard, is a square specimen cut from the glued sheets. The glueline-cleavage specimen is the only one which meets this requirement and has been given a rating of 1. Possibly the next simplest is the cross-lapped specimen with a rating of 2. The block shear specimen requires two extra saw cuts which complicates its manufacture. In addition it is necessary to glue additional material to both sides when the test is used with sheet materials in order to prevent failure occurring in compression parallel to the shearing force rather than in shear as intended. The tension shear specimen also requires two extra saw cuts which complicate the manufacture. In the case of hardboard, the depth of these saw cuts would be quite critical, which would further slow up the preparation of specimens as well as reduce the accuracy of the test. The tension normal method requires the gluing of grips to both backs. The block shear and tension normal methods have been given a rating of 3. Percent wood failure specimens have been rated at from 1 to 3, depending upon the type of specimen from which the fibre failure readings are obtained.

Requirements of the ideal Method of Test	BLOCK SHEAR	TENSION SHEAR	TENSION NORMAL	CROSS-LAPPED	GLUELINE CLEAVAGE	Per Cent Wood Failure
Reproducibility or Accuracy	1	1	2	2	1	4
Results in Pounds	1	1	1	1	1	3
Simplicity of Test Specimen	3	3	3	2	1	1 to 3
Cost of Equipment	3	3	3	3	1	1 to 3
Adaptability to both Research and Production	1	1	1	2	1	1
Maximum Stress concentrated in a single known area	2	2	2	2	1	2
Time to Conduct Test	2	2	2	2	1	1 to 2
Max no of Test Specimens per unit area of glueline	2	3	1	2	1	1 to 3
TOTAL	15	16	15	16	8	17½

These factors are apart from the overall requirement that the test must estimate the desired strength property of the material

Figure 1.—Author's rating of test methods.

4) Under *cost of equipment*, the glueline-cleavage test has a rating of 1, the percent wood failure method from 1 to 3, and the others a rating of 3.

5) Under *adaptability* to both *research and production control testing*, all have been rated as 1, except the cross-lapped specimen, which has been given a rating of 2.

6) The sixth requirement listed is that the *maximum stress shall be concentrated in a single known region of the glue line*. This glueline-cleavage test is the only one which meets this requirement. It has been given a rating of 1 and the others a rating of 2.

7) The time required to conduct a test is less for the glueline-cleavage test than for any of the others, with the possible exception of the percent wood failure method. The rating for the glueline-cleavage test being 1, that of the percent wood failure method would be 1 when used with the knife test and 2 when used with the tension shear specimen, as is most commonly done. The other methods have been given a rating of 2.

8) The final criterion listed is that the maximum number of test specimens be obtainable from a given area of glue line. For production testing this is probably of no importance, but for research purposes, where large numbers of specimens must be matched as closely as possible, it can be a very important factor. The tension normal and glueline-cleavage tests are the only two which meet this requirement, and have been given a rating of 1. The percent wood failure method has been rated at from 1 to 3, depending upon the type of specimen used. The block shear and cross-lapped specimens have been rated at 2, and the tension shear at 3.

These eight requirements are separate from the over-all requirement that the test must estimate the desired strength property of the material.

With this method of rating, the test having the smallest total has the highest rating. This is the glueline-cleavage test with a rating of 8. The others have ratings of 15, 16, 15, 16, and 17½. The system used to rate these methods of test is not sufficiently accurate to differentiate between ratings as similar as 15 and 16, but should be sufficiently accurate to demonstrate differences between ratings as dissimilar as 8 and 15. This system of rating, as mentioned before, is based upon experience with wood. Whether or not the rating would be the same for hardboard remains to be shown.

A comparison was made between the *tension normal* and the *glueline-cleavage* breaking loads of several fibre boards ranging in density from 0.25 to 1.45. The results are indicated in Figure 2. Each point plotted is the mean of five tests. The coefficient of correlation between tension normal and glueline-cleavage methods was very high, 0.977. Figure 3 shows the correlation of glueline-cleavage with tension normal for hardboard glue lines. Three hardboards and two glues are represented. The glue lines were purposely made weaker than the hardboard so as not to confuse bond strength with hardboard strength. Again the correlation between the two methods was good, though not as good as before. The coefficient of correlation is 0.896.

It is believed the three charts, Figures 1, 2 and 3, present sufficient evidence to warrant a thorough investigation of the glueline-cleavage test as a gluability test for hardboard.

Discussion

Q. Why could not the speed of test for any of these different methods of testing be changes so that a rating of 1 could be given if that were desired?

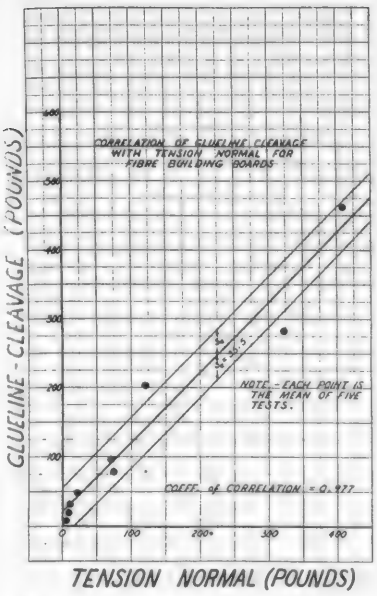
CORRELATION OF GLUELINE CLEAVAGE WITH TENSION NORMAL FOR FIBRE BUILDING BOARDS
NOTE - EACH POINT IS THE MEAN OF FIVE TESTS.
COEFF. of CORRELATION = 0.977
GLUELINE-CLEAVAGE (POUNDS)
TENSION NORMAL (POUNDS)

Figure 2.—Comparison of tension normal and glueline-cleavage breaking loads of several fibre boards.

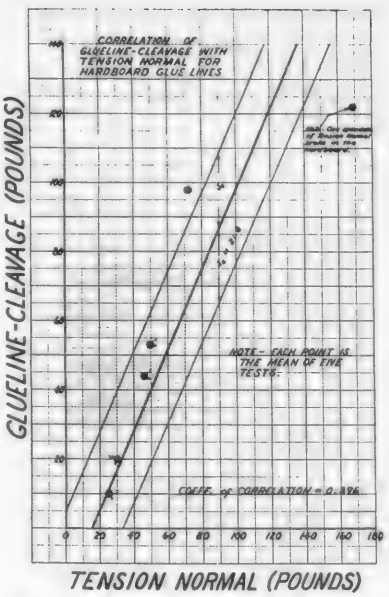
CORRELATION OF GLUELINE-CLEAVAGE WITH TENSION NORMAL FOR HARDBOARD GLUE LINES
NOTE - EACH POINT IS THE MEAN OF FIVE TESTS.
COEFF. of CORRELATION = 0.896
GLUELINE-CLEAVAGE (POUNDS)
TENSION NORMAL (POUNDS)

Figure 3.—Correlation of glueline-cleavage with tension normal for hardboard glue lines.

A. It is our understanding that the recommended head speeds for tests such as the plywood shear and block shear were set at the highest speed at which the average operator could run the machine and still obtain accurate readings of the breaking loads. In our experience it takes approximately twice the time to conduct a plywood shear or a block shear test as to conduct a glueline-cleavage test.

Q. Why are not block shear, cross-lapped and tension shear given a 1 rating as regards the item "maximum stress concentrated in a single known area" in Figure 1?

A. First let me emphasize that it is *maximum stress* which is under discussion, not average stress. When one takes the breaking load in pounds of a test specimen and divides this figure by the area stressed, one obtains an average stress for that area. The intensity of this stress varies throughout the specimen, usually being a maximum at the edges or at any sharp angle such as at the base of a saw cut, and a minimum at the centre of the stressed area for which the average stress has been calculated. In our opinion it is not the average stress which causes a specimen to fail, but local stress concentrations which exceed the strength of the wood and which then spread rapidly from the position of initial failure until complete failure occurs. For a discussion of the stress distribution in test specimens, reference could be made to the Department of Scientific and Industrial Research "Report of the Committee on the Mechanical Testing of Timber", London, His Majesty's Stationery Office, 1934, and to Cousins, F.W., "Determining Stress in Glued Joints by Photo-elastic Method", Timber News, Vol. 58, No. 2127, January, 1950. To get back to the specific question, the plywood shear test specimen has two regions in which maximum stress may develop simultaneously; namely, at the base of each of the two internal saw cuts. In the case of the block shear specimen, there are also two regions in which the maximum stress may be developed, one at each end of the glue line to be sheared. In the case of the tension normal and cross-lapped specimens, there are four such regions, either along the four edges or at the four corners.

In the case of the glueline-cleavage, there is just one possible position for the maximum stress to develop; namely, in contact with the knife edge. Causes of failure can, therefore, be related to one position in each specimen rather than to two or more possible positions. Calculation of the intensity of stress at any point in any test specimen is difficult, if not impossible, but that is hardly a valid reason for ignoring the fact that the stress does vary throughout the specimen. Until such time as someone succeeds in calculating the stress distribution in a test specimen, it will be necessary to base comparisons upon the breaking loads of standardized test specimens. For the purpose of such comparisons it is considered preferable, from a theoretical standpoint, to base these comparisons upon the breaking loads in pounds rather than upon the average stress which one obtains by dividing the breaking load by the test area of the specimen.

Q. Referring to the ratings in Figure 1 under "Results in Pounds", could not the p.s.i. be considered more important, and could not the glueline-cleavage test then have a rating of 6 or 7?

A. This question has been partially answered in the reply to the previous question. One other point should, however, be mentioned. This is the evidence which was first introduced in support of the theory that the stress in a wooden test specimen is not uniform across the test area but varies from point to point.

The evidence which prompted a critical study of the distribution of stress intensities in test specimens was, it is believed, first presented in the Third and Final Report of The Adhesives Research Committee, Department of Scientific and Industrial Research, London, His Majesty's Stationery Office, 1932. Data are given to show that stresses in simple lap (tension shear) specimens of different areas are not constant when reduced to pounds per square inch of glue line tested, but vary from 1252 p.s.i. for a one inch lap to 2334 p.s.i. for a one-quarter inch lap. With this type of specimen, therefore, dividing the breaking load by the cross-section of the glue line does not give a realistic measure of the magnitude of the stresses which caused failure of the specimen. This being the case, it is more logical to present results of such tests as breaking load in pounds for a standardized size and shape of test specimen than to present them as p.s.i. It is not intended to imply that the conclusions which have been drawn from experiments when the results have been expressed as (average) p.s.i. would have been any different had the figures been expressed as breaking load for a standardized test specimen—quite the contrary. It is considered, however, that more critical study of the actual stress disribution will, in the future, lead to more accurate interpretations of the results of mechanical tests and that until that day arrives test results should not be stated as p.s.i. but as the breaking load in pounds for that specimen. An attempt has been made with partial success to calculate the stress at any point in the glueline-cleavage specimen.

Q. Why is the rating 1 for glueline-cleavage and 3 for other tests under "cost of equipment" in Figure 1?

A. The glueline-cleavage machine which was used for all of the work to date cost approximately $25.00. Testing machines, such as the type which is used to conduct plywood shear, block shear, or the other test mentioned, would have cost approximately one hundred times as much. Such a difference in the cost of equipment could

influence a small manufacturer's decision as to whether or not to introduce a quality-control program. This is the reason for the different ratings in this case.

Q. Is not the criterion under "accuracy" (Figure 1) questionable, since when failure is forced at a certain point, as in the knife cleavage, the value obtained may be more a measure of the test itself than any test of the material itself?

A. I am assuming that the mean of this query is—"Is reproducibility of test results a good criterion of accuracy?" It is no doubt true that a machine of poor sensitivity could yield results which do not differ greatly one from the other, but this could happen only in a situation where all specimens to be tested were of approximately the same strength. When specimens with a wide range of strengths are tested, and the machine demonstrates these differences, this possibility would seem to be discounted. The error variance in a family of test results is, in principle, the sum of the variance attributable to the testing machine plus that attributable to the material being tested. Now if the same material is tested by two methods, and one method consistently yields a smaller error variance, it seems logical to conclude that this method is the more accurate. Therefore, it seems to me that reproducibility of test results, when properly used, can be a useful measure of relative accuracies of different methods of test.

Application of Available Glue Line Test Methods to Hardboard[1]

A. H. RAUCH

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Discusses standards and specifications for hardboard and wood applicable to testing of hardboard-to-wood glue joints. Covers work by the Plywood Research Foundation and others using Commercial Standard CS45–48. Tests involve standard and tempered types of hardboard glued to Douglas fir plywood and lumber with interior and exterior type glues. Data are also included on testing of commercial Plyron (hardboard hot-pressed to face and back of plywood using exterior glues).

IN CHECKING THROUGH the various standards and specifications for wood and wood products, U. S. Commercial Standard CS45–48 seemed to offer a good possibility as a test method for determining the quality of hardboard glue joints. A.S.T.M. D805–52 lists similar tests plus a dry-shear test that may be applicable, but does not include the 10-cycle soaking and drying test of 6 by 6 inch specimen

Some of the other standards and specifications available for possible use in testing hardboard glue lines are the following:

1. ASTM D1037–52T—Tentative Method of Test for Evaluating the Properties of Fiber Building Boards.
2. ASTM D1101–50T—Tentative Method of Test of Integrity of Glue Joints in Laminated Wood Products for Exterior Service.
3. Federal Specification LLL–F–311 March 9, 1939—Amended May 13, 1952.
4. Hardboard Association Proposed Standards.

It was concluded that none of the above included testing procedures that would be appropriate for testing hardboard-to-wood glue lines.

Briefly, the tests included in U. S. Commercial Standard CS45–48 and used in obtaining data for this paper may be described as follows: Shear specimens for dry test, cold soak test and boil test are all cut to the same dimensions of 1 by 3¼ inch with kerfing at approximately third points to give exactly one square inch of shear area. In plywood the grain of the ply next to the hardboard is normally perpendicular to the long axis of the test specimen but when a single solid piece of wood is glued to hardboard the specimen is cut with the grain parallel to the long axis (figures 1, 2). This was done because the hardboard was applied to only one face and therefore the grain had to be parallel to get good loads. On hardboard–plywood assemblies the kerf is cut through to the hardboard–plywood glue line from the plywood side and then through this glue line to the next glue line from the opposite hardboard side of the test specimen. In the case of solid pieces of wood and hardboard, this last kerf is taken to the same (the only) glue line as the first. In testing the specimens are placed in parallel gripping jaws and a load is applied at a rate of 600 to 1000 pounds per minute until failure. Load in pounds is noted and wood failure is estimated. The dry-shear specimens are tested at 8 to 12 percent moisture content. The cold soaks are submerged in water at room temperature for 48 hours and dried for 8 hours at a temperature of 145° F. (± 5° F.) followed by two cycles of soaking for 16 hours and drying for 8 hours as above, then soaked again for 16 hours and tested wet. The boil specimens are submerged in boiling water for 4 hours, dried at 145° F.

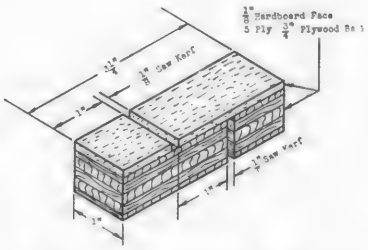

Figure 1.—Shear specimen based on Commercial Standard CS45–48.

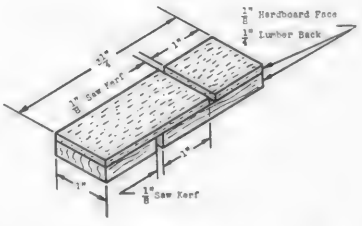

Figure 2.—Shear specimen based on Commercial Standard CS45–48.

[1] Presented at the meeting of the Hardboard Division of the FPRS Pacific Northwest Section at Aberdeen, Washington, May 17, 1954.

The Author, A. H. Rauch, is in charge of wood technology at Plywood Research Foundation. He is a graduate of Oregon State College, was formerly employed by Forest Products Laboratory and Weyerhaeuser Timber Company.

(± 5° F.) for 20 hours, boiled again for 4 hours and tested wet.

The 10-cycle test requires that 6 by 6 inch specimens (figure 3) be submerged in water at room temperature for 4 hours, then dried for 20 hours at a temperature not to exceed 100° F. This cycle is repeated until all specimens have failed or have completed 15 cycles (known as 10-cycle test because specimens completing 10 or more cycles without failure are considered as passing). Individual delaminations of the glue line being tested of ¼ inch or more in depth and over 2 inches in length along the edge of the 6 by 6 inch test piece shall be considered a failure. For the purpose of obtaining comparative values to use in this paper test specimens were arbitrarily rated in percent according to the number of cycles through which they passed without failure, ten cycles constituting 100 percent.

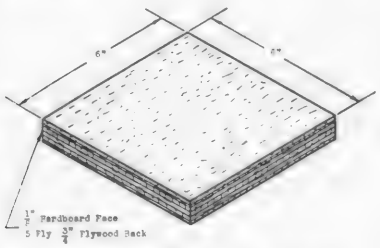

Figure 3.—Ten-cycle specimen based on Commercial Standard CS45–48.

Exterior Hardboard Glue-Joints

A group of seven different hardboards were glued to one side of ¾ inch exterior type plywood panels using cold-setting resorcinol-formaldehyde glue. The back side of the hardboards (normally screenback) was used as the gluing surface. The glue was applied to the plywood by mechanical laboratory spreader at a rate of approximately 60 pounds per 1000 square feet of double glue line. The closed assembly time was about 10 minutes and a pressure of 175 p.s.i. was applied for 8 hours at room temperature. All plywood and hardboard was conditioned before and after gluing for at least one week at 75° F. and 50 percent relative humidity.

Ten panels were made up with each type of hardboard and from each panel 5 shear specimens were cut for the delamination[2] test. Four additional shear specimens were cut from each of 5 of the above panels and tested according to the exterior boil test listed in CS45–48, Paragraph 13b, previously described. The results of the above two tests are listed in Table 1 and indicate

[2] This is simply an observation test of the amount of delamination, if any, in standard shear test specimens after exposure to boiling and drying according to CS45–48.

Table 1.—BOIL TEST RESULTS HARDBOARD GLUED TO PLYWOOD WITH EXTERIOR COLD PRESS GLUE[1]

Hardboard[2] Number	Shear Test: Breaking Load	Shear Test: Percentage of Failure in: Hardboard	Wood	Glue Line	Delamination[3] Test
1	145[4]	20	77	3	1 V S
2	208	30	49	21	1 V S
3	113	48	51	1	None
4	117	79	21	0	None
5	131	94	6	0	None
6	70	39	0	61	6 S to M
7	146	60	40	0	4 V S to S None

[1] Resorcinol Formaldehyde type.
[2] Hardboards numbered 1 and 2 were ⅛ inch tempered type, the rest of the boards were ⅛ inch standard except number 7 which was 1/10 inch standard.
[3] One by 3¼ inch specimens were given boil test according to CS45–48 and then examined for amount of delamination and arbitrarily rated as None, Very Slight (V S), Slight (S) and Marked (M) each rating listed covers fifty test specimens.
[4] Each value represents an average of 20 tests, 4 from each of 5 different glued up panels.

some variation in the glueability of the different hardboards using this particular adhesive. Two of the boards had glue failure averages of 21 and 61 percent as measured by the boil-shear test method and could be considered questionable and below standard respectively. The delamination test showed one "very slight" rating out of 50 (98 percent good) for the board with 21 percent glue failure and 10 "very slight" to "marked" ratings (80 percent good) for the board with 61 percent glue failure, indicating this test might not be too reliable. The shear test after boiling produced rather consistent results under these controlled laboratory conditions with the glue lines showing up repeatedly good or poor depending upon the hardboard used. The 61 percent glue failure of board number 6 was very likely the result of its very rough and rather deep screen back pattern which prevented intimate contact.

A series of boil-shear tests were made on commercial hardboard glued to both sides of plywood (known in the trade as Plyron). These tests included 16 panels from each of which 5 test specimens were cut and tested. The average results of these tests are as follows: Load 164 p.s.i., Hardboard Failure 53 percent, Wood Failure 39 percent and Glue Failure 8 percent. These panels were made using hot-press phenolic glue and tempered type hardboards and it would be normal to expect good durable glue bonds. The 92 percent average wood plus hardboard failure obtained by the above test method indicates such a bond.

Interior Hardboard Glue-Joints

Using the same gluing techniques as outlined in the first paragraph of *(exterior) hardboard glue-joints* 10 panels were made up with each of 7 hardboards using urea glue. A similar series was made up using casein glue spread at a rate of 120 pounds per 1000 square feet of double glue line, and finally a group was made up using hot-animal glue spread by hand at approximately the same weight of spread as the casein but held for a closed assembly time of less than 2 minutes and pressed only 10 minutes. Each of these panels was cut into three 6 by 6 inch test specimens for the cyclic soaking and drying test described in CS45–48, giving a total of 30 test specimens for each of the hardboards and glues used.

After conditioning for at least one week at 75° F. and 50 percent relative humidity all specimens were tested according to the 10-cycle interior test listed in Paragraphs 11, 12 and 14a of CS45–48. The results of these tests are listed in Table 2 and indicate again some variation in the glueability of the different hardboards. Number 4 board was rated at 16 percent with casein glue whereas the average of all boards glued with casein was 74 percent. Hardboard number 6 averages 34 percent for all glues while the average of all glues for all hardboards was 72 percent. The average rating for animal glue was 56 percent, for casein 74 percent and for urea for 87 percent. The test procedure would appear to be satisfactory in that these percentage ratings follow in general the water resistance normally expected of the three glues. The average rating of 74 percent for casein may be slightly lower than normal inasmuch as board number 4 had a rating of only 16 percent and this may have been due to some peculiarity of this board, such

Table 2.—10-CYCLE TEST RESULTS HARDBOARD GLUED TO PLYWOOD WITH VARIOUS INTERIOR GLUES

Hardboard Number	Glue: Animal %	Casein %	Urea %	Average All Glues %
1[1]	72[2]	84	100	85
2	70	94	100	88
3	53	98	98	83
4	42	16	100	53
5	46	92	81	73
6	38	33	32	34
7	70	100	100	90
Glue Avg.	56%	74%	87%	72%

[1] Hardboards numbered 1 and 2 were ⅛ inch tempered type, the rest of the boards were ⅛ inch standard except number 7 which was 1/10 inch standard.
[2] Each value is the average of 30 individual tests. Percent refers to the number of cycles through which test specimen passes without failure; 1p cycles being 100%, 8 cycles 80%, etc.

Table 3.—DRY AND COLD SOAK SHEAR-TEST RESULTS OF TWO TEMPERED HARDBOARDS GLUED TO DOUGLAS FIR LUMBER WITH FOUR DIFFERENT ADHESIVES

Glue	Dry Shears				Cold Soak Shears			
	Load psi	Hardboard Failure %	Wood Failure %	Glue Failure %	Load psi	Hardboard Failure %	Wood Failure %	Glue Failure %
	Hardboard Number 1							
Resorcinol	251[1]	15	85	0	282	65	35	0
Urea	249	50	50	0	268	64	20	16
Casein	380	70	25	5	---	--	--	--
Animal	262	20	74	6	---	--	--	--
	Hardboard Number 2							
Resorcinol	334[1]	30	70	0	150	50	50	0
Urea	313	15	85	0	131	32	10	58
Casein	354	50	50	0	---	-	--	--
Animal	348	45	54	1	---	-	--	--

[1] Each value is an average of 20 tests; 5 each from four individual panels, except for urea cold soaks which are averages of 10 tests; 5 each from two panels.

as excessive absorption of the glue into the board (starved-joint). Also, in regard to casein glue the moisture content of some of the hardboards may have been lower than optimum. Board number six as previously mentioned had a very coarse, deep screen back pattern which may have affected the casein and urea glue bonds more than animal glue joints (33 and 32 percent as compared to 38 percent).

Another series of test panels have been made up following similar laboratory gluing technique as discussed previously for each of the 4 glues resorcinol, urea, casein and animal. In this series, however, the hardboards were glued face or smooth side down to one quarter inch thick Douglas fir lumber and the shear specimens were cut with the grain of the wood parallel to their long axis. Four panels were made up with each glue and each of two tempered type hardboards. From each of the panels five test specimens were cut for dry shear tests and five additional specimens were cut from the urea and resorcinol glued panels for the cold soak test previously described and listed in Paragraph 13a of CS45–48.

Results from the above tests have been averaged and will be found in Table 3. The dry-shear data indicates all of the glues are satisfactory for bonding these particular hardboards for strictly interior use, however, the dry tests do not indicate how well the glue bonds might hold up under limited moisture exposure conditions such as might occur in concrete forms, etc.

Comparing the cold soak shear-test data on urea glue to that glue in Table 2 shows that the 10-cycle test is much less severe on this glue. Hardboard plus wood failures of 84 and 42 percent for hardboards number one and two by the cold soak shear test method would indicate some weakness of the bond to this type of exposure, but the 100 percent ratings for the same boards by the 10-cycle method showed excellent resistance to the conditions of this test.

A comparison of Table 2 and 3 in regard to animal glue shows dry shear hardboard plus wood failures of 94 and 99 percent for the two hardboards used and only 72 and 70 percent ratings for the same hardboards by the 10-cycle method. This cyclic exposure test, therefore, brings out the lower moisture resistance of animal glue in hardboard to wood glue-joints.

Conclusions

The rather limited data available has been presented in order to try to learn something of the applicability of standard test methods to the testing of hardboard glue-joints. Since new methods of glue line testing are being explored as the hardboard industry develops, the data included should be of value in developing any new or improved testing procedures.

In regard to the testing procedures applicable to the evaluation of exterior type bonds in hardboard glue lines, the boil-shear tests with wood and hardboard failure estimation is the most severe but also appears to be the most dependable. The "delamination" test does not always show up bond weaknesses as is shown in Table 1 where the rating of this test is compared with that of the boil test. The cold soak test may have some application but certain glues such as urea might pass this test with relatively high wood and/or hardboard failures of over 50 percent and still not be of a quality to withstand continuous outdoor weathering.

As to the techniques that might be applicable to measuring the quality of interior glue lines in hardboard it appears from the data in Table 2 and 3 that either the dry-shear or 10-cycle test would be pertinent depending upon the moisture resistance desired. The percentage hardboard plus wood failure in the dry-shear test is a fair indication of the adequacy of the bond for strictly interior use (dry application). The 10-cycle test rating gives an indication of how well the interior glue joint will perform under conditions of limited exposure such as occasional wetting and drying at approximately room temperature. Table 2 substantiates this in showing an average rating for all hardboards of 56 percent for animal glue, 74 percent for casein and 87 percent for urea. These ratings are approximately correct for the expected durability of the above type of glue under the exposure conditions involved.

Summary

The dry, cold soak and boil, shear tests and the 10-cycle soaking and drying tests have applicability in determining the quality of interior and exterior type hardboard glue-joints. However, adaptations of these tests or the development of new testing procedures to better cover the variability of hardboard would undoubtedly assist those involved in working out improved specifications or standards. This variability in such properties as density, hardness, porosity or absorptiveness and softening or strength loss in water at room temperature or boiling is in my estimation of primary importance in any work to be done on new or improved glue line testing procedures.

Acknowledgement

Acknowledgement is given to those in the Allied Products and technical departments of the Douglas Fir Plywood Association who have so generously assisted me in gathering the data necessary for this paper.

Effect of Rays on Radial Shrinkage of Beech[1]

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Description of the results of tests made to obtain information on the radial shrinkage of broad and fine rays of beech, and the effect of varying the proportion of ray tissue contained in transverse sections on the radial shrinkage of the sections.

THERE HAS BEEN, in recent years, considerable controversy as to the cause of the difference between the radial and tangential shrinkage of wood. Different theories, published by investigators, variously explain this differential transverse shrinkage on the basis of the fine structure of the cell wall, on the amount of middle lamella present between cell walls per unit length in the radial and tangential directions, or on the shrinkage interaction between springwood and summerwood.

It was formerly thought that the rays restricted shrinkage in the radial direction but did not restrain tangential shrinkage. Investigations by Barkas (1)[2](2), Clarke (3), and Greenhill (4)(5)(6), have supported this theory. Kollman (7), Ritter (11), and Ritter and Mitchell (12)(13), however, have rejected the theory that differential transverse shrinkage is due to the ray cells. In fact, Ritter and Mitchell have stated (13):

> "From the foregoing data and discussions, it appears that ray cells may be omitted from the various factors that cause less radial than tangential shrinkage of wood".

In a recent report (9) the author has shown that the shrinkage of broad rays of red oak (*Quercus borealis* Michx. f.)—isolated from the surrounding wood—was about one-half as much radially as the shrinkage of the adjacent vertical tissue, free from the influence of board rays but, of course, containing fine ray tissue. Lindsay and Chalk (8) obtained similar results with isolated broad rays of *Quercus ilex*, *Cardwellia sublimis* and *Helicia terminalis*. It is of importance to note that specimens described and measured by Lindsay and Clark as containing "no ray tissue" appear to be free of only "broad rays". The "fine rays" which may occupy at least as much of the volume of wood as the broad rays could influence the radial shrinkage of the wood if their shrinkage properties are similar to those of the broad rays.

Tests have been continued at the Ottawa Laboratory, of the Forest Products Laboratories of Canada, to obtain information on the shrinkage of rays of beech (*Fagus grandifolia* Ehrb.) and to determine the effect of rays on the radial shrinkage of the wood. This report describes the results with regard to the radial shrinkage of broad and fine rays of beech, and shows the effect of varying the proportion of ray tissue contained in transverse sections on the radial shrinkage of the sections. Extrapolation of a curve indicating this relationship is made to arrive at a theoretical value for the radial shrinkage of beech wood free of all rays.

Material and Methods of Testing

Specimens used for the investigation originated in a tree of beech (13.0 inches d.b.h.—o.b.), felled at the Petawawa Forest Experiment Station, Petawawa, Ontario, in December 1952. The test logs were immediately transported to the Ottawa Laboratory where they were held in water storage to avoid drying. The method of cutting transverse sections from small water-saturated blocks which had received no previous treatment was similar to that previously described for the red oak investigation (9). Measurement at saturation and in the dry condition was made by means of a travelling microscope using certain anatomical features in the wood as reference points. Drying of the specimens was accomplished over phosphorous pentoxide as described previously.

Isolation and Partial Separation of Broad Rays for Shrinkage Measurements: Transverse sections, about 80 microns in thickness and containing a portion of at least one broad ray, were cut from the small water-saturated blocks. The broad rays were carefully separated from the adjacent wood on both sides of the broad ray for the entire radial length of the sections. Isolation of the broad rays was made by means of a scalpel while the specimens, in the water-saturated condition, were being viewed under a dissecting microscope at X12 magnification. The resulting portions of the transverse sections, some consisting of ray tissue and others of wood free of broad rays (but containing fine rays), were placed on glass slides in water, covered with a cover glass, and measured to obtain the saturated radial dimensions. The specimens were then dried over P_2O_5, as mentioned above, and the dimensions in the dry condition were measured through a plate-glass desiccator top by means of a travelling miscroscope.

In order to illustrate the difference between radial shrinkage of broad rays and that of the surrounding wood, a number of transverse sections were dissected while water-saturated so that broad rays were only partially isolated from the wood on each side. Photomicrographs were taken of the specimens in the "lab.-dry" condition (approximately 8 per cent moisture content).

Specimens to Indicate Radial Shrinkage of Fine Rays: Because of extremely small tangential dimensions of fine rays, it was, of course, impossible to isolate fine rays in a manner similar to that used for broad rays for determination of radial shrinkage.

Small fragments of transverse sections were, however, successfully isolated in a saturated condition by means of a scalpel so that a fine ray would lie along one radial edge of the specimen. The small sections were allowed to dry without restriction under normal laboratory atmospheric conditions and the behaviour on drying was observed under a dissecting microscope. The photomicrographs of the sections in the "lab.-dry" condition illustrate the distortions caused by the difference in the radial shrinkage of fine rays and the vertical cells surrounding them.

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[1] This contributed article is essentially part of a thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Department of Wood Technology, State University of New York, College of Forestry, at Syracuse.

[2] Numbers in parentheses refer to literature cited.

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Determination of Volume of Wood Occupied by Ray Tissue: In order to assess the effect of ray tissue on the radial shrinkage of wood, it was necessary first to determine the volume of wood occupied by broad and fine rays.

Because of the variation in the distribution of broad rays per unit volume of wood and since variations in tangential dimensions of different broad rays are apparent, it is difficult to evaluate precisely the volume of wood occupied by broad rays. However, an estimation of the volume of wood composed of broad ray tissue was made from microscopic observation of a number of tangential and transverse sections.

Since the number and size of fine rays per unit volume of wood for any one species is relatively constant, measurement of the area on a tangential plane occupied by fine rays compared to that occupied by other wood tissue gives a ratio which can be transformed to percentage of the volume of the wood occupied by rays. It is difficult to estimate the area of a tangential section occupied by fine ray tissue either by inspection through a microscope at relatively low magnification or by measurement with the aid of an eyepiece micrometer at high magnification. For this reason, the method used to determine the volume of wood occupied by the fine rays was somewhat similar to that used by Myer (10).

Tangential sections, 15 microns in thickness, were cut from the summerwood of beech and were prepared as temporary mounts in glycerine and water. Photomicrographs of the tangential sections cut from four blocks were taken on 8 by 10 inch film at a magnification of X150. Areas to be photographed were selected between broad rays so as to include only fine rays and vertical cells. From the prints made of each film, portions representing fine rays were cut out, weighed, and their weight compared to the weight of the portions of the prints representing the surrounding wood. This made it possible to arrive at a value for the approximate volume of wood, free of broad rays, occupied by fine ray tissue.

Specimens Containing Different Proportions of Ray Tissue: To ascertain the effect of different proportions of ray tissue contained in transverse sections on the radial shrinkage of the sections, and since the ray content within a species is relatively uniform, it was necessary to devise a method of producing, in different sections, various relative proportions of ray tissue and vertical cells. It was decided that by varying the amounts of wood (vertical cells and fine rays) attached to broad rays in transverse sections, the actual proportions of ray tissue within the section would, in effect, be varied. Transverse sections, 80 microns in thickness and containing at least one broad ray, were, therefore, prepared from water-saturated blocks of beech under test.

Separated Radially

Isolation of the broad rays, with different amounts of surrounding wood tissue (vertical cells and fine rays) attached to the broad ray, was made by means of a scalpel while the sections, at saturation, were being viewed under a dissecting microscope. In order to avoid the possibility of curvature of the sections on drying, separation was carefully made in a radial direction so that as far as possible, within each section, the same amount of wood was present on each side of the broad ray. Measurement of the portion of each dissected section occupied by the broad ray was made with the aid of an eyepiece micrometer while the sections were saturated with water.

Earlier tests—using the same procedure of isolation—indicated that for measurement of radial shrinkage it was necessary to locate reference points some distance from the tangential edges because of the "edge effect". The edge effect on the tangential edges of transverse sections is caused by the difference in radial shrinkage of the broad ray and the surrounding wood. Differences in radial shrinkage were apparent depending upon the distance from the broad ray. Therefore, vessels lying adjacent to the broad ray, and two annual rings distant from each tangential edge, were selected as reference points for measurement of radial dimensions at saturation and in the dry condition.

Because of the difficulty of isolation, no sections were prepared containing over approximately 55 percent broad ray tissue. The total amount of ray tissue in each section was computed from information giving the percentage of broad ray tissue in the section added to the estimated percentage of fine rays contained in the wood on each side of the broad ray. These data, indicating the relation between radial shrinkage of transverse sections and the percentage of the sections occupied by ray tissue of red oak and beech, are shown herewith in tabular and graphical form.

Observations and Results

Radial Shrinkage of Broad Rays: The results of measurements of the radial shrinkage of broad rays of beech isolated from transverse sections, 80 microns in thickness, and of the wood of beech without broad rays (i.e., containing vertical cells and fine rays), also isolated from transverse sections of the same thickness, are given in Table 1. These data show that the radial shrinkage of wood without broad rays is about 3 times the radial shrinkage of isolated broad rays.

Table 1.—RADIAL SHRINKAGE OF BROAD RAYS AND OF WOOD WITHOUT BROAD RAYS

Material* Measured	Number of Specimens	Mean Radial Shrinkage %	Standard Deviation
Wood without broad rays	14	6.73	0.15
Broad rays	10	2.32	0.06

*Transverse sections, 80 microns in thickness

Deformation of Transverse Sections with Broad Rays Partially Isolated: Figure 1 illustrates the deformation in a transverse section of beech containing a broad ray and allowed to dry under normal laboratory atmospheric conditions. The waves, or ripples, occurring in the broad ray and in wood adjacent to the broad ray, are caused by the difference in radial shrinkage.

Portions of transverse sections isolated with a broad ray along one radial edge curved on drying so that the ray was always along the convex radial edge. This is illustrated in Figures 2 and 3. The sections illustrated were, of course, straight when water-saturated. The specimen in Figure 3 was cut from a saturated block about 5.5 cms. in radial length. When allowed to dry in the air, the section curved to an almost complete circle because the radial shrinkage of the broad ray was less than that of the wood beside it.

The bow-shaped deformation shown in Figure 4 was produced by dissecting a transverse section, (80 microns in thickness) at saturation so that the broad ray was present along one radial edge and fibrous wood (and fine rays) along the other. The broad ray was then separated by means of a scalpel from the fibrous wood throughout most of its length, the natural attachment of ray and adjacent wood remaining at both ends of the section. When the section was dried in the air, the bow-shaped deformation resulted because of a greater radial shrinkage of the fibrous wood than that of the broad ray.

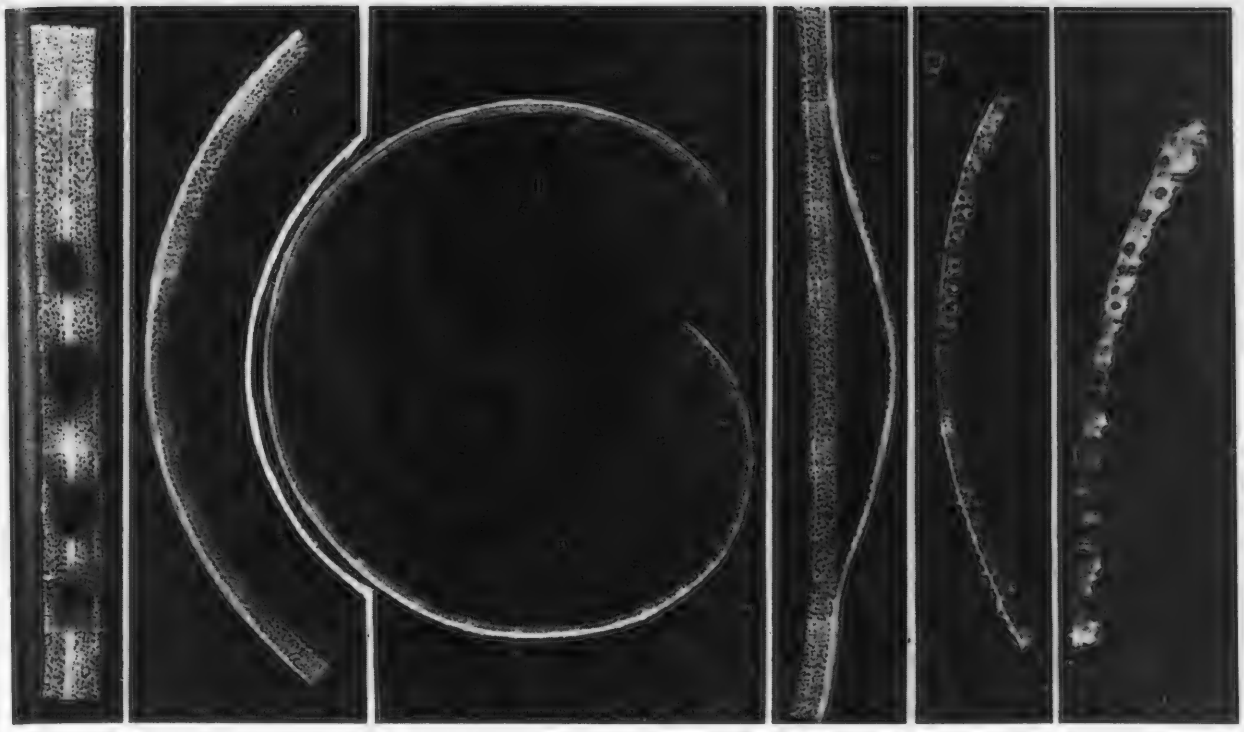

Figure 1.—Transverse section of beech showing "waves" in broad ray due to greater radial shrinkage in surrounding wood than in ray. Photographed in "lab.-dry" condition. (Magn. X10.)

Figure 2.—Curvature of a portion of a transverse section of beech when dried to "lab-dry" condition. (Magn. X10.)

Figure 3.—Transverse section of beech isolated with a broad ray along one radial edge. Curvature in dry condition resulted from less radial shrinkage in the broad ray than in the vertical cells. (Magn. X6.)

Figure 4.—Bow-shaped deformation in transverse section of beech. Photographed in "lab.-dry" condition. (Magn. X10.)

Figure 5.—Portion of a transverse section of beech isolated with a fine ray (3 cells wide) along one radial edge. (Magn. X18.)

Figure 6.—Fragment of transverse section with fine ray (1 cell wide) along radial edge. (Magn. X50.)

Radial Shrinkage of Fine Rays: It was previously mentioned that because of the small tangential dimensions of fine rays of beech, it was impossible to separate the fine rays from transverse sections for measurement of their radial shrinkage in a manner similar to that employed with the broad rays. Small transverse sections, however, were isolated so as to contain a fine ray on one radial edge and vertical cells on the other. Photomicrographs illustrating the effect of fine rays on radial shrinkage are presented as Figures 5 and 6.

Figure 5 shows the curvature resulting when a small portion of a transverse section containing a fine ray, 3 cells in width, was allowed to dry under laboratory atmospheric conditions. Similarly, Figure 6 illustrates the curvature of a specimen which contained a fine ray, 1 cell in width, along a radial edge.

All small fragments of transverse sections of beech dissected with a fine ray at or near one radial edge curved in drying so that the fine ray was always on the convex radial edge of the specimens. This illustrates that the fine rays shrink less radially than the vertical cells surrounding them and must, therefore, influence the behaviour of wood shrinking in a radial direction.

Volume of Wood Occupied by Ray Tissue: As mentioned previously, broad rays of beech vary in tangential dimensions, some being wider than others. As viewed on a transverse section, differences in width are apparent in a single broad ray. The portion of the ray near the division between two annual rings is wider than elsewhere. It is also to be noted that the distribution of broad rays within the wood is not uniform. For these reasons, it was decided that only estimates were possible of the volume occupied by broad rays in the wood under test. Estimates were made on several transverse and tangential sections viewed at relatively low magnification. Results show that a reasonable estimate of the total volume of wood composed of broad rays is about 6 per cent for beech.

Results of tests, in which the fine ray volume was measured on temporary mounts of tangential sections by cutting out the portions of photomicrographs representing fine rays and comparing the weight of these portions of the prints with the weight of the remaining portions, indicate that the volume of wood, between broad rays, occupied by fine rays is approximately 16 per cent for beech.

It is estimated, therefore, that the total volume of wood of beech occupied by ray tissue (broad and fine rays) is approximately 21 per cent.

Radial Shrinkage of Transverse Sections Containing Different Proportions of Ray Tissue: The results of tests to determine the influence of different proportions of ray tissue on the radial shrinkage of transverse sections of beech are shown in Table 2. Since it was found that fine rays occupied about 16 per cent of the volume of wood of beech free of broad rays, the percentage of the sections occupied by ray tissue (broad and fine rays) has been entered in this table.

Table 2.—RADIAL SHRINKAGE OF TRANSVERSE SECTIONS CONTAINING DIFFERENT PROPORTIONS OF RAY TISSUE

Approximate Proportion of Section Occupied by			
Broad Rays %	Ray tissue* (broad and fine rays) %	Number of Specimens	Radial Shrinkage of Sections %
0**	16	14	6.73
6	21	2	5.92
10	24	4	5.54
15	29	3	5.27
23	35	4	4.39
30	41	5	3.76
40	50	2	3.53
46	55	1	2.84
100**	100	10	2.32

*Based on fine ray volume of 16 per cent of total wood without broad rays.
**Data taken from Table 1.

It can be seen in Table 2 that, as the percentage of ray tissue contained in transverse sections increases, the radial shrinkage of the sections decreases. These data are graphically illustrated in Figure 7.

It should be noted that sources of error are present when determination is made of the volume of the transverse sections occupied by ray tissue as reported in Table 2. Errors may occur in the estimation of the volume of the sections occupied by broad ray tissue because of the variation in tangential dimensions within one broad ray, and because of the difficulty in determining precisely the amount of wood associated with the broad rays in different sections. The possibility exists also that the volume of wood occupied by fine ray tissue in the different sections may not, in all specimens of beech, be exactly 16 percent. For these reasons, it is repeated that figures in Table 2 giving the proportion of the sections occupied by ray tissue are to be considered as reasonable approximations and not as exact measurements.

Radial Shrinkage of "Rayless" Wood from Experimental Data: The experimental data presented in Table 2 giving the radial shrinkage of transverse sections containing different proportions of ray tissue in beech have been plotted in Figure 7. The curve has been extrapolated to zero ray volume to obtain a theoretical radial shrinkage value for transverse sections without any ray tissue. The curve indicates that the radial shrinkage of beech sections free of ray tissue would be about 11.7 percent.

It is realized that extrapolation of the relationship shown in Figure 7 is hazardous because of the steep slope of the curve as it approaches a ray volume of 16 percent. The extrapolation is also based upon the assumption that the radial shrinkage of fine rays is similar to that of broad rays and that the fine rays restrict the radial shrinkage of the surrounding wood. This has been verified, as far as possible at present, from observation of distortions on drying that are manifested by small transverse sections containing a fine ray on one radial edge. (See illustrations.)

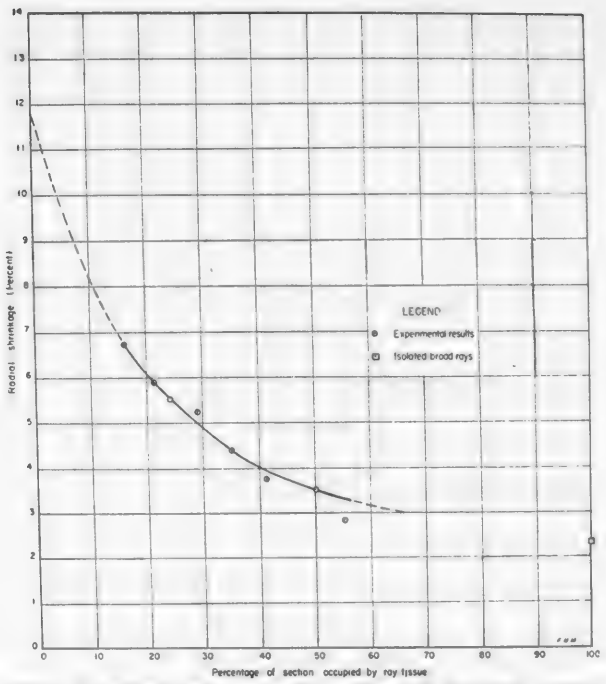

Figure 7.—Relation between radial shrinkage of transverse sections of beech and volume of sections occupied by ray tissue.

Discussion

Experimental results presented in this article have shown that the radial shrinkage of broad rays of beech is 2.32 percent compared to 6.73 percent for wood (vertical cells and fine rays) free of the influence of broad rays. Photomicrographs of the distortions on the drying of transverse sections in which broad rays were only partially isolated have illustrated the difference between the radial shrinkage of the broad rays and that of the surrounding wood. Observation has shown that all transverse sections, isolated with a broad ray along one radial edge, curved on drying so that the broad ray was on the convex edge. These results agree qualitatively with those previously reported for red oak.

Curvatures of small transverse sections of beech, isolated so as to contain a fine ray at or near one radial edge, have indicated that the fine rays also shrink less in a radial direction than fibrous cells surrounding them. It is, therefore, reasonable to believe that the fine rays possess a shrinkage potential in a radial direction which is similar to that of broad ray tissue.

The experimental measurement data, obtained from tests to determine the effect of different proportions of ray tissue contained in transverse sections of beech upon the radial shrinkage of the sections, have shown the significant effect of rays in restraining the shrinkage of wood in a radial direction. Extrapolation of the curve illustrating this relationship to zero ray volume has indicated that the theoretical radial shrinkage for transverse sections of beech without rays is about 11.7 per cent. As was previously indicated, extrapolation of the curve is rather difficult because of the steep slope of the curve as it approaches 16 percent ray volume.

The value of 11.7 percent for the radial shrinkage of "rayless" wood is approximately equal to the tangential shrinkage (11.6 percent) of springwood and summerwood of beech shrinking in unison, determined on transverse sections. From investigations of both red oak and beech it would appear that rays are of major importance in causing the radial shrinkage to be less than the tangential shrinkage.

An equation has been derived mathematically to determine the radial shrinkage of wood without rays and to indicate the effect of the rays on the strength of wood in the radial and tangential directions. It is expected that the derivation along with information on tangential-radial shrinkage ratios of springwood and summerwood of red oak and beech will be published shortly.

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Drying Stresses in Red Oak[1]

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The effect of relative humidity variation on tensile and compressive stresses, perpendicular to grain, during drying of 2-inch red oak at 110° F. is reported. The general pattern of strains was the same as previously found for other hardwoods. Details were affected by humidity differences. Both external set and internal set occurred. The external set tending to decrease shrinkage, was proportional to severity of humidity schedule. Shrinkage, strain, and external set started while only a small portion of the wood was below 30 percent moisture content. The centers were still above 30 percent when maximum internal tensile strain occurred.

EARLY STUDIES in the air drying and kiln drying of wood at the Forest Products Laboratory disclosed that internal stresses of considerable magnitude are built up in the wood as it dries. Knowledge of the nature and magnitude of these stresses is important both for understanding the fundamental physical properties of wood and for the practical development of kiln schedules, control of material dimension, and relief of residual stresses and sets. Numerous experiments at the Forest Products Laboratory have yielded valuable information about these stresses. Only during the past few years, however, has it been possible to get under way a comprehensive investigation of this subject. The studies have been made on red oak, one of the most important Eastern woods and one that takes so long to dry that any resultant savings in drying time will be very well worthwhile. This report covers the first study in the series. It concentrates on the effects of relative humidity changes on tensile and compressive stresses in 2-inch red oak during kiln drying at 110° F.

A general concept of how the stresses develop inside of wood as it dries can be gained by visualizing the moisture content gradient as observed on a cross section of a board after one-tenth of its total moisture has been evaporated. The outer zone appears to be dry; at the very surface it is down below the fiber saturation point. Thus, the fibers at the surface are dry enough to try to shrink. Their shrinkage is restrained, however, by the underlying wood, which is in a relatively green condition and above the fiber saturation point. Because of this restraint, the outer fibers are stressed in tension. As a reaction, the inner fibers are stressed in compression. These stresses are perpendicular to the grain of the wood. As the wood continues to dry from the outside, the zone attempting to shrink moves further in towards the center. The outer zone becomes drier and drier. As it loses its moisture, it becomes set in a dimension close to the green dimension. Because of this set in the outer zone, when drying progresses to where the interior fibers begin to go below the fiber saturation point and want to shrink, the stresses reverse. The interior undergoes a tensile stress while the exterior is subjected to compression. It is during the first stage, exterior tensile stress, that surface and end checks tend to form. During the second stage, that of internal tensile stress, surface and end checks tend to be converted into honeycomb checks. Under some circumstances, honeycomb may form spontaneously.

Early wood tehnologists (1)[4] in this country knew about the need to avoid set in obtaining good shrinkage values. The term "caseharden" had come into use by 1895, and Roth (4) recognized that there was some connection between casehardening and checking. Tiemann (5), however, probably was the first to begin to understand stresses and set in wood and to make prong analyses of stresses. A short while later, Tiemann (6) made a hypothetical slice analysis of drying stresses. All through this period of early exploration, only general knowledge of drying stresses was gained. Such knowledge probably was helpful, however, in setting up the

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[3] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

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[4] Numbers in parentheses refer to Literature Cited at end of paper.

conservative kiln schedules and set-relief methods appropriate for the drying equipment then in use.

So far as the author is aware, however, the first attempts to actually measure stress analysis slices and to follow the development and reversal of stresses from the beginning of drying through conditioning were made at the Forest Products Laboratory in 1924 by E. C. Peck. In 1929, W. K. Loughborough, then on the Laboratory staff, used prong measurements to demonstrate set and its relief. Also, about this time staff member O. W. Torgeson and collaborators W. L. Greenhill and Ian Langlands started to study the strength of wood in tension perpendicular to the grain at different moisture content values and at different temperatures under Loughborough's supervision.

When the woodworking industry began to make considerable use of southern hardwoods, it was only natural for kiln-schedule research on them to turn to stress analysis. Peck used the slicing technique on magnolia, among other woods. Results on blackgum (2) were published in 1940. This work indicated that drastic lowering of relative humidity could be used after the reversal of stresses. A subsequent, more comprehensive study on sweetgum heartwood was made by Loughborough and H. H. Smith, and the results were published in the Kiln Certification Manual (8). Later Rietz (3) described how the principles developed in these studies were used in setting up a new concept of kiln drying schedules. In 1951, Torgeson (7) brought out a whole new series of kiln schedules for American woods based on these principles.

To make further advances in kiln schedules and to shorten the work of developing schedules for foreign woods that have no established schedules, a more thorough knowledge of the effect of drying conditions on internal stresses is required. To gain this knowledge is the objective of the present series of studies. The procedure used is the slicing technique. Sections are cut from the wood at various times in the drying period. The sections are measured at various places across the thickness of the piece, then they are cut into slices to release the stresses. The slices either contract or elongate. The difference between measurements before and after slicing is taken as an indication of the strain to which the wood was subjected as a result of the stresses. Without any method of measuring the stresses directly, the observable strains give us valuable information on them. Contraction is an indication of tensile stress; elongation is an indication of compressive stress.

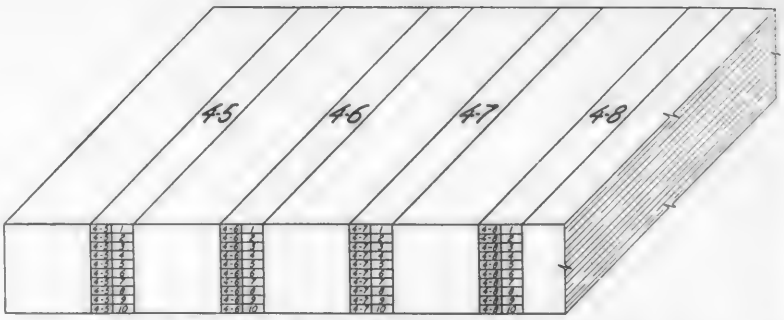

Figure 1.—Method of marking test specimens.

Material Tested

The material used was green, flat-sawed 2-inch red oak, presumably *Quercus rubra,* obtained in plank form from a sawmill in Sauk City, Wis. The rough planks, 2⅛ inches by 8 inches by 8 feet were kept wet in a 35° F. storage room pending use. Test specimens 5 feet long and free from defects were obtained by dressing both broad faces and trimming and dressing the narrow faces to a green width just under 7 inches. The ends were coated with aluminized phenolic-resin varnish, and the specimens were protected from drying during preparation and measurement. Initial moisture content was about 90 percent, specific gravity was 0.57 and number of rings per inch was about 9.

Test Methods

Each experimental run consisted of drying one test specimen in a small internal-fan kiln with automatic control of temperature and humidity. Each green specimen was marked off with a 1-inch section every 3 inches along the grain Each section was marked for 10 slices, as shown in figure 1 The slices were numbered consecutively, beginning at the side of the specimen toward the convex side of the rings The width of the green specimen was measured between midpoints on the ends of each slice and recorded These measurements were used to compute shrinkage of the board as a whole at various intervals of drying, and to compute also the ultimate shrinkage of the slices when dried to an ovendry condition.

The prepared specimen was placed in the kiln on stickers, and void space was baffled so that air velocity over the specimen's surface was about 250 to 400 feet per minute. After each interval of drying, one section was cut off the specimen and wrapped in foil. The remainder was end coated and replaced in the kiln. While the section was still intact, the width of each slice was measured to get the before-cutting dimension, as in figure 2. The differences between the green dimensions and the before-cutting dimensions, converted to a percentage-of-green-dimension basis,

Figure 2.—Measurement of slices in section before cutting.

were used as indications of shrinkage of the board as a whole. Then the section was laid on its side, and the slices were marked on the cross section by indelible carbon paper. The foil wrapper was removed, and the section was rapidly cut into slices on a thin bandsaw. Each slice was enclosed in a tared foil wrapper, then measured as shown in figure 3 for the after-cutting dimen-

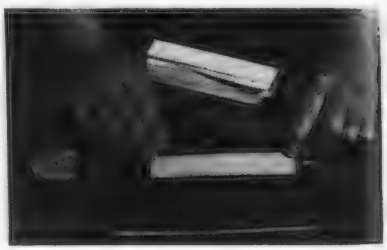

Figure 3.—Remeasurement of slices after cutting.

sion. The differences between the before-cutting and after-cutting measurements, converted to a per-inch basis, were considered as unit strains. After measurement, each wrapped slice was weighed. Then the slices were unwrapped, piled in a stickered bundle by use of the jig shown in figure 4, and carefully dried so as not to induce any new set. Drying generally consisted of 1 day in the kiln at 110° F. and 80 percent or more relative humidity, 1 day in the room, and 1 day in the oven at 214°–221° F. When ovendry, the slices were cooled in a dessicator, then reweighed for moisture content calculations and remeasured for ultimate slice-shrinkage calculations. Differences be-

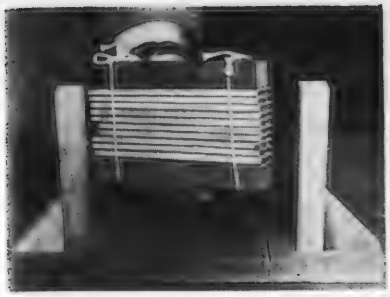

Figure 4.—Stickered bundle of slices ready for careful drying to determine set.

tween observed ultimate shrinkage and the inherent shrinkage of the wood were considered indications of set.

The drying schedules varied from run to run to show the effect of relative humidity variations at a 110° F. temperature. Changes generally were made at points of comparable loss of evaporable moisture (E).

$$E = \frac{\text{Current moisture content—equilibrium moisture content}}{\text{Original moisture content—equilibrium moisture content}}$$

In the five runs covered by this report, dry-bulb temperature was held constant at 110° F. until E was down to 0.25 or 0.30, then raised to 120° F., and finally at E = 0.20 or 0.25, raised to 130° F. In all runs, the first reduction in relative humidity was made when E = 0.60. In runs 1, 2, and 3, the humidity-reduction pattern was a mild one, with succeeding reductions at E values of 0.52, 0.45, 0.38, 0.30, 0.25, and 0.20. In run 4, the relative humidity was reduced about the same amounts as in the previous runs, but more rapidly in terms of evaporable moisture. In run 5, the same relative humidity drop was made at E = 0.60, as in previous runs, but when tensile strain in the outer zone had receded to 80 percent of its maximum value, relative humidity was abruptly dropped to 26 percent.

Results

Tension and Compression: The unit strains observed in run 3 are shown in figure 5. Drying time, average moisture content of the specimen, and kiln conditions are shown at the bottom of each bar graph. Relative humidity conditions have been converted to wood equilibruim moisture content (E.M.C.) values at that temperture and relative humidity. Preliminary runs 1 and 2 were made with essentially the same schedule but for only the first 20 days of the run. They gave essentially the same results. They are not reported here, but their more frequent observations during the first phase of the runs justifies the smooth curves shown in the succeeding figures.

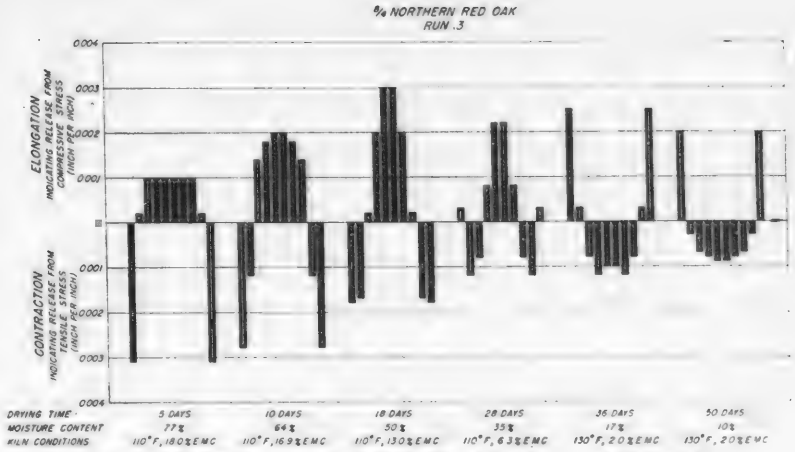

Figure 5.—Strain diagrams for 2- by 7-inch red oak dried at 110° F. with a mild humidity schedule.

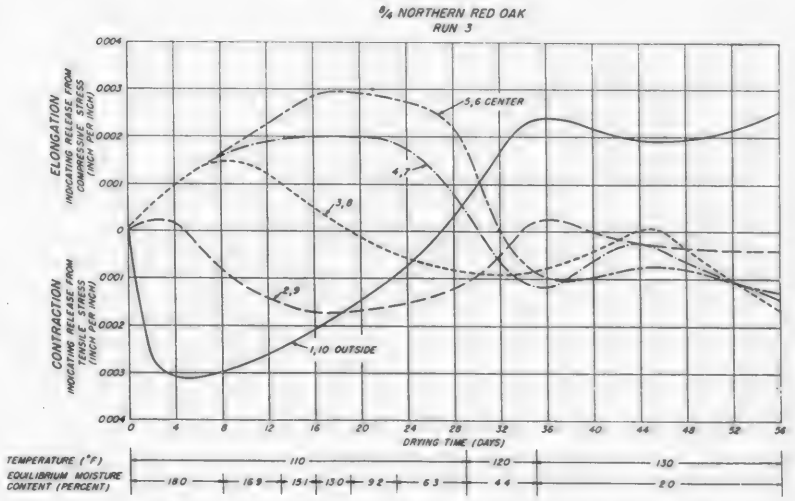

Figure 6.—Strain curves for 2- by 7-inch red oak dried at 110° F. with a mild humidity schedule.

At the end of 5 days of drying, the specimen in run 3 had dried to 77 percent moisture content. The maximum tensile strain of the outer slices, about 0.003 inch per inch, had been attained. For the purpose of this analysis, the results of the two slices equidistant from the center were averaged, and the average value was assigned to each. Often there was considerable difference between these individual values.

At the 5-day point, only the outer slices were in tension. Slices 2 and 9 were in slight compression. All other slices showed a compressive strain of about 0.001 inch per inch. After 10 days of drying and the first slight change in relative humidity, average moisture content was 64 percent. The outer slices still had a great deal of tensile strain. Slices 2 and 9 had gone into tension. The interior slices had greater compression. After 18 days of drying, moisture content had dropped to 50 percent. Slices 2 and 9 had reached maximum tension of about 0.0017 inch per inch, but tension was still slightly greater in slices 1 and 10. The center slices reached a maximum of compression, 0.003 inch per inch. Compressive strain in slices 3 and 8 had dropped almost to 0.

At the fourth stage, after 28 days, the moisture content was at 35 percent, and reversal of stresses had started. In the fifth stage, after 36 days, reversal was complete. Moisture content was down, on the average, to 17 percent. Compressive strain of the outside slices had reached a maximum of almost the same magnitude as their maximum tensile strain at the start. Remember, these are strains, not actual stresses. The stresses for the same strains become considerably greater as moisture content goes down. The sixth bar graph shows strains as the wood enters its final drying stage at 10 percent moisture content, with the outside in compression and all interior slices in tension.

In terms of the effect of the stresses on wood, the danger of surface checking was greatest during the first stage

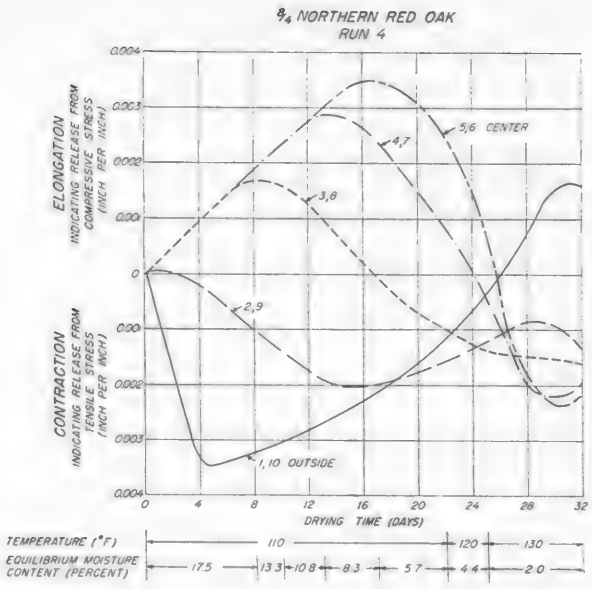

Figure 7.—Strain curves for 2- by 7-inch red oak dried at 110° F. with a medium humidity schedule.

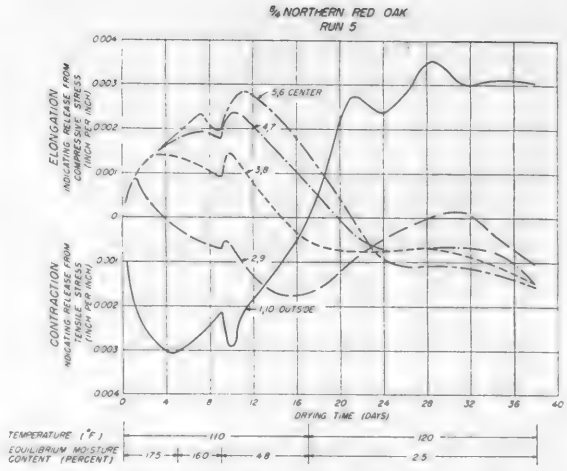

Figure 8.—Strain curves for 2- by 7-inch red oak dried at 110° F. with a severe drop in relative humidity.

of drying, when the tensile stress in the outer zones was the greatest. The possibility of compression set or compression collapse was greatest when the compressive stress in the center zones was greatest. The condition promoting honey-comb was the worst when the outer zones were at maximum compressive stress and the inner zones at maximum tensile stress. The final condition of the wood is what we know as casehardening.

Figure 6 shows a linegraph of the strain curves in run No. 3. The data for runs Nos. 1, 2, and 3 generally justify the smooth curves drawn, but small irregularities, which are not shown, did occur. Some of these no doubt were experimental errors; some of them probably were not.

Figure 7 shows a linegraph of strain curves for run No. 4. In this run, a medium rate of relative humidity reduction was followed. The effect was slightly higher maxima of tensile and compressive strains, plus a considerable pushing together of the curves timewise. Stress reversal occurred at 26 days. The maximum tensile strain in the center slices after stress reversal, 0.0023 inch per inch, was greater than the maximum with the milder schedule.

Figure 8 shows the strain curves for run No. 5. In this run, the initial conditions were the same as run No. 4. The second condition also was mild. Then, when the tensile strain in the outer slices had fallen off to 80 percent of its maximum value, the relative humidity was drastically lowered to a 4.8 percent equilibrium moisture content condition. This resulted in an increase of tensile strain in the outer slices, but to a value less than the maximum that occurred at 5 days. Considerable increases in compressive strain occurred in the third, fourth, and fifth slices. All zones appeared to have resumed their normal strain patterns after 2 days of exposure to the new conditions. Sweetgum (3,8) had not shown such a disturbance of strain curves when relative humidity was abruptly dropped. It is, perhaps, significant that checking did not occur under the increased tensile stress. The actual stress in pounds per square inch probably was greater at this point because the wood was drier and had a higher modulus of elasticity. On the other hand, the resistance to checking probably was higher also.

In general, all the results showed the same general strain pattern and with about the same maxima of tensile and compressive strains at the 110° F. temperature studied. Differences in amount and rate of relative humidity lowering, however, did alter the details of the strain pattern.

Board Shrinkage: Measurement of the slices "before cutting" showed that the shrinkage of the specimen as a whole began immediately upon the start of drying. Figure 9 shows the shrinkage-time curves for outside and center slices of run No. 3. During the first part of drying, the outer slices were forcing the contraction of the board as a whole, as represented by the center slices. After stress reversal, the center slices were forcing the contraction of the outer slices. The observed shrinkage of the center slices, before slicing, was always less at any particular time than that of the outer slices because the center slices were always higher in moisture content than the outer slices.

Shrinkage continued at a uniform rate until about the 26th day, which marked the point of stress reversal for slices 1 and 10. There was a jump in shrinkage rate until the 40th day, which was slightly after the first maxima of the reversed strains had been passed. Thereafter, shrinkage proceeded at about the same rate as during the first 26 days of the run. A similar board-shrinkage relationship was found for run No. 4, only shrinkage rates were somewhat faster. Figure 10 shows the shrinkage curves for run No. 5. In this run, there was an abrupt jump in board

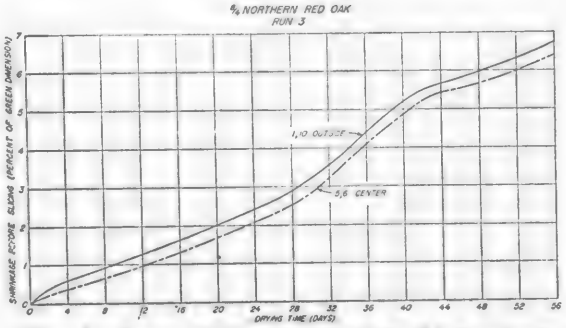

Figure 9.—Board-shrinkage curves for 2- by 7-inch red oak dried at 110° F. with a mild humidity schedule.

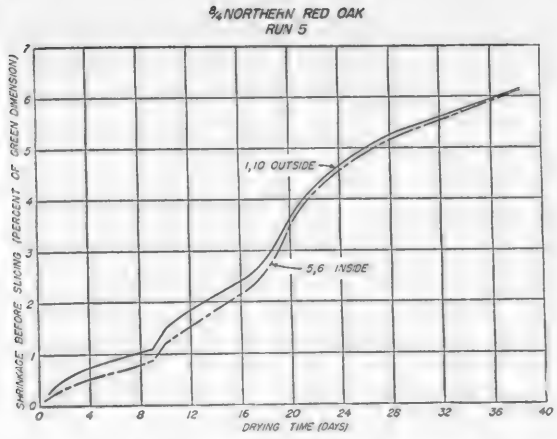

Figure 10.—Broad-shrinkage curves for 2- by 7-inch red oak dried at 110° F. with a severe drop in relative humidity.

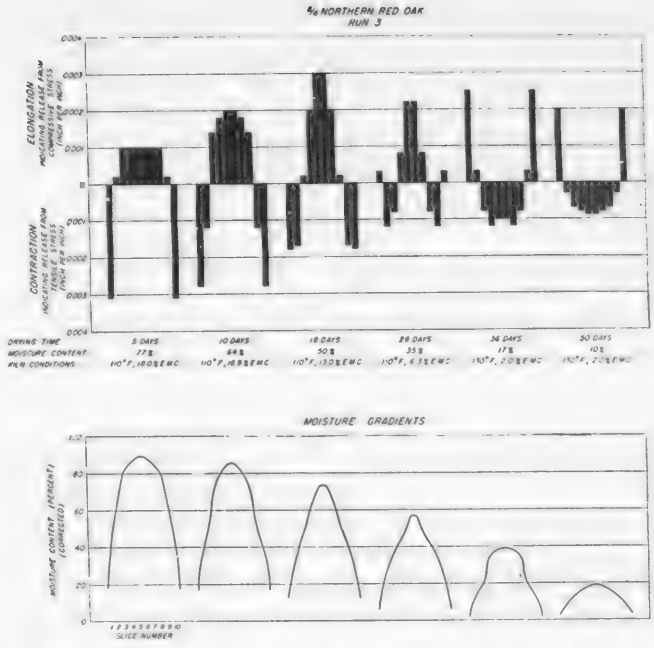

Figure 12.—Strain diagrams and moisture gradients for 2- by 7-inch red oak dried at 110° F. with a mild humidity schedule.

shrinkage after 9 days, when relative humidity was drastically lowered. Then, because of the low equilibrium moisture content, shrinkage continued at a rapid rate. Again there was an upswing in the curves during the period of 18 to 24 days of drying. After this, the rate was about the same as for run No, 3.

Set: Stresses and strains are always involved when wood is dried. Another thing that usually occurs is called set. Set is defined as a permanent deformation occurring when the wood has been strained beyond the proportional limit. In other words, if the load or stress were released, the wood would not return to its original dimension. An engineer might define set as a strain remaining after removal of stress.

One way to determine the presence of set is to observe ultimate shrinkage to the ovendry condition of a portion of the wood and compare it to the normal shrinkage of set-free wood. Set does not remove the wood's inherent tendency to shrink,, but it modifies the observed shrinkage. When a strip of wood is set while under a tensile stress, its observed shrinkage is less than normal shrinkage. The magnitude of the difference between observed shrinkage and true shrinkage is a measure of set.

The formation of a set in the outer zones, while the wood is under tension, has been recognized and accepted in lumber-drying technology for many years. Although not so readily recognized, the compressive stresses inside of wood may be so great as to strain the wood beyond the proportional limit, and give it a set making its apparent shrinkage greater than normal shrinkage. The data in this study give positive indications along this line.

Figure 11 shows ultimate shrinkage curves for slices in runs Nos. 3 and 5 as a function of drying time. Here again the somewhat irregular data have been smoothed out to give the curves shown. This and subsequent research have shown that a very careful slice-drying technique is required to avoid extraneous set effects. In this study, it appeared that immediate placement of the stickered bundle of slices in a kiln at 110° F. and an equilibrium moisture content of 16 percent or higher for 1 day, followed by 1 day in room conditions at 70° to 80° F., and 1 day in the oven was satisfactory.

In the graphs of figure 11, it may be assumed that slices 2 and 9 had the most nearly normal shrinkage because, as shown in figures 6 and 8, they departed least from the zero strain line in the first part of the run. The normal shrinkage of run No. 3 was thus 7.7 percent, and normal shrinkage of run No. 5 was 8.7 percent. Set developed immediately in the outer slices in both cases. In run No. 3, the development was gradual, and maximum set in the outer slices was not attained until 22 days. Thus, set was still building up after maximum tensile strain had passed and continued almost until tensile strain dropped tn zero. External set formed more rapidly and to a greater degree in run No. 5. Here again, the maximum did not occur until the 14th day, when the tensile strain was nearly back to zero. Slice shrinkage curves were not prepared for run No. 4, but they would be expected to show intermediate results.

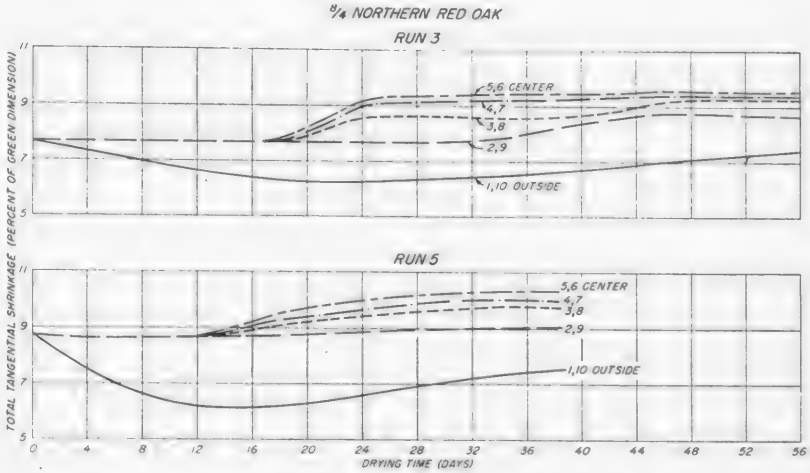

Figure 11.—Total shrinkage of slices in runs Nos. 3 and 5, showing influence of set.

An internal set apparently did occur in both runs. In run No. 3, the start of internal set occurred on the 18th day. This coincided with the time to maximum compressive strain in the center slices. Slices 4 and 7 exhibited almost as much internal set as slices 5 and 6, and slices 3 and 8 exhibited only slightly less. The magnitude of the maximum set in both directions was about the same; that is, about 1.8 percent of green dimension. In run No. 5, internal set started on the 12th day, again about the time of maximum compressive strain. Here the magnitude of the internal set was considerably less than that of the external set. The magnitude of the internal set was somewhat less than that in run No. 3.

In both runs, the external set was relieved or counteracted somewhat by long-time loading under compressive stress after stress reversal. Somewhat higher temperatures after 29 days in run No. 3 and after 17 days in run No. 5 probably had a part in this relief.

In run No. 3, there was an upswing in shrinkage of slices 2 and 9. Subsequent research has shown that this upswing is a common occurrence under most conditions. The significance of the upswing and why it did not occur in run No. 5 are not known. In the case of run No. 3, however, the start of the upswing coincides with a brief interval when slices 2 and 9 were in compression.

Moisture Gradients: In considering the development of drying stresses in wood, it must be recognized that moisture content plays an important part. Strength values are inversely proportional to moisture content below the fiber saturation point. Dry wood is much stronger than green wood. The strength to proportional limit, the maximum strength, and the stress-strain ratio are all influenced by moisture content. Shrinkage also is inversely proportional to moisture content below the fiber saturation point. By definition, there should be no shrinkage above the fiber saturation point. Information on the moisture content of the slices at various stages should be of primary interest in interpreting the foregoing strain, shrinkage, and set data.

Such data for run No. 3 are shown in figure 12. The averaged and smoothed moisture gradients for various pairs of slices are shown in the upper portion of the figure. At the time of maximum tensile strain in the outer slices, only a small portion of these slices was below 30 percent moisture content. Similarly, the greater portion of slices 2 and 9 was above 30 percent when, as shown in the third bar graph, these slices were at their maximum tensile strain. In this condition, they were subject to low proportional limits and high plasticity. Thus, they were susceptible to permanent deformation or set. As shown in the third bar graph, when the interior slices were under maximum compressive strain, they were far above the fiber saturation point. Even when stresses had reversed and the interior slices were under maximum tensile strain, they were still above the fiber saturation point, as shown in the fifth bar graph. Thus, they would be very susceptible to honeycombing at this stage, if temperature were raised drastically. These interior moisture content values above 30 percent existed when the moisture content of the 2-inch stock was down to 17 percent. Experience has generally shown that high final kiln temperatures must be avoided until the wettest point in the interior, usually the midthickness, is below the fiber saturation point. The average moisture content for 2-inch stock is lower for this point than the average for 1-inch stock because of the hump-shaped moisture gradients common to thick stock of slow-drying species in contrast to the parabolic curves of 1-inch stock.

Effect of Temperature: Subsequent research with similar red oak, and using a mild relative humidity reduction schedule, has shown that the general strain pattern is the same for temperatures ranging from 80° F. to 140° F. In general, the maximum tensile strain in slices 1 and 10 and the maximum compressive strain in slices 5 and 6 are about the same order of magnitude in all cases up to 125° F. At 140° F., the maximum tensile strain of slices 1 and 10 is considerably greater, and the maximum compressive strain of slices 5 and 6 is considerably less than those at the lower temperatures. External set in slices 1 and 10 is about the same in most cases, but internal set in slices 5 and 6 varies considerably with temperature. The details of these data are the subject of another paper.

Conclusions

1. Red oak was shown to experience the same general pattern of internal stresses during drying as was previously found in sweetgum heartwood, blackgum, magnolia, and other hardwoods.

2. This stress pattern is such as to cause surface and end checking and external set during the first stage, internal set during the second stage, honeycombing during the third stage, and leave the wood in a casehardened condition.

3. Maximum tensile strains in outer slices and maximum compressive strains in center slices were approximately the same order of magnitude for the different humidity schedules tested, but these maxima and reversals of stresses occurred earlier with more rapid rates of relative humidity reduction.

4. In red oak, it is possible to reestablish near maximum tensile strain in the outer zones by abrupt reductions of relative humidity after the maximum has been passed. Corresponding increases in compressive strains can occur in the interior zones. The specimens in this study did not check under such conditions.

5. Set, or permanent deformation, occurred in the drying of oak, both a set tending to decrease shrinkage in the outer zones and a set tending to increase shrinkage in the interior zones. The magnitude of the external set was proportional to the severity of the relative humidity schedule.

6. Shrinkage of the whole boards occurred from the start of drying and continued on a steady rate until accelerated during the period between stress reversal in the outer zones and the first maxima of the reversed stresses; thereafter shrinkage resumed a steady rate.

7. The shrinkage rate was abruptly increased by an abrupt lowering of the relative humidity during the first part of the drying.

8. Shrinkage, tensile strain, and external set all started when only a small portion of the wood was below the fiber saturation point.

9. Moisture content in the center was still above the fiber saturation point when maximum internal tensile strain occurred.

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A Method for Determining the Elastic Constants of Wood by Means of Electric Resistance Strain Gages[1]

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The use of electric resistance strain gages on wood for the determination of elastic constants is explained. A method for finding moduli of rigidity from a compression test at an angle to the grain is introduced.

AMONG THE MOST SENSITIVE and versatile strain measuring devices perfected in recent years are the bonded wire electric resistance strain gages. A diagrammatic sketch of a bonded wire gage is shown in figure 1. The active component of the gage is a grid of very fine wire firmly cemented to a paper backing. The gages are fixed to

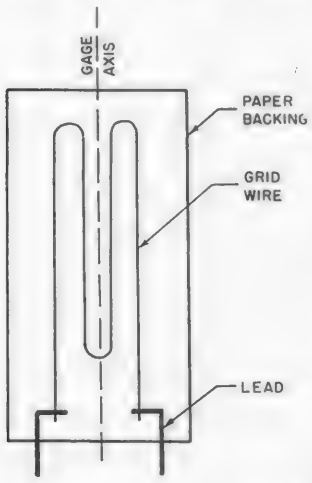

Figure 1.—Diagrammatic sketch showing the elements of a bonded wire strain gage.

the surface of the part to be tested by cellulose acetate cement. As loads applied to the test part cause strains in the material beneath the gage, the wires of the grid follow these strains in the direction of their axes, thus changing their electric resistance. Many electric and electronic instruments are available for measuring such resistance changes. The relation between the resistance change and the strain that caused it is called the gage factor. Since gage factors are linear, it is possible to design the measuring instruments to read directly in strain rather than resistance change.

[1] A contributed paper.

The Author, Byron M. Radcliffe, received B.S. and M.S. degrees from Purdue University. He was instructor in mechanics and strength materials in the School of Civil Engineering, Purdue, from 1948–51. Since 1951 he has been engaged in wood mechanics research in the Department of Forestry.

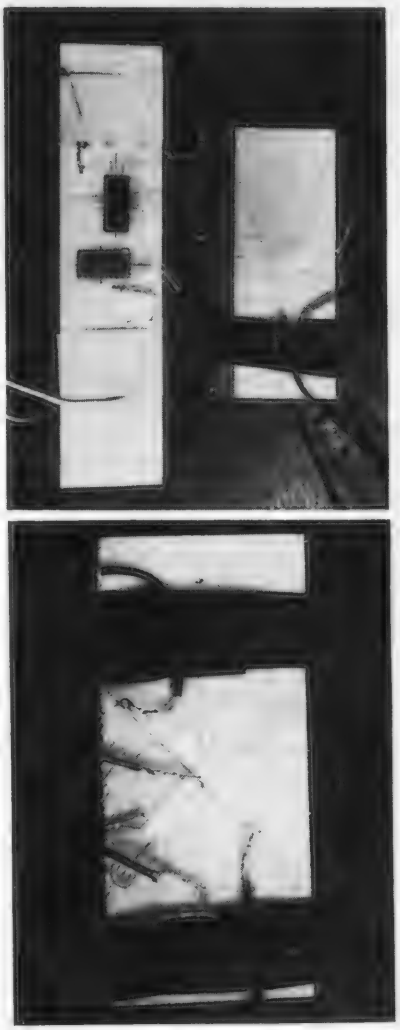

Figure 2.—(a) Installations on wood of types A-5 and A-7 gages. (b) A-7 gages mounted as a rectangular rosette.

With the gages, then it is possible to determine the strains in a part resulting from a known externally applied force system. If the elastic constants, or stress-strain relationships, are known for the material of the test specimen, an experimental stress anlaysis may be conducted.

These gages have found extensive use in many fields of experimental stress analysis. However, the agencies involved in wood research have been slow to realize their potentialities. A major problem to be realized in gage applications with wood is the large variations of elastic constants from piece to piece, even within a single species. For each analysis it is necessary to determine the constants for the particular piece from which the test specimen is made. It is the purpose of this paper to present a simple method of finding these constants by means of the resistance gages.

Most of the stress analysis problems with wood which have been studied at the Wood Research Laboratory have involved the use of SR–4 types A–5 and A–7 strain gages. Figure 2 shows installations of these gages on wood specimens. A typical instrumentation set-up is shown in figure 3. The instrument at

Figure 3.—Instrument set-up for use with resistance strain gages.

the left is a switching unit which makes it possible to follow several strain gages during the same loading cycle. In the same figure, the unit in the center is the strain indicator, essentially a sensitive but rugged Wheatstone bridge. Power is supplied by the transformer to the right.

When electric resistance strain gages are used on wood, there are a few special precautions that should be followed. It is essential to prepare the surface by applying a liberal (but smooth) coat of cement, which is allowed to dry before the gages are cemented into position. The size and type of gage to be used, with regard to width as well as length of grid, should be sufficiently large to cover a representative area of annual increment—but not so large as to obscure the evaluation of strains in a limited area, for plane stress is a point to point consideration. Also, because wood is a

rather poor conductor of heat, thermal drift may be quite pronounced. Error due to this phenomenon may be minimized by providing each active gage with its individual temperature compensating gage in the switching unit. The compensating gages should be of the same lot as the active gages and mounted on matched material at the same angular orientation with respect to the grain direction. The compensating gage is wired in the leg of the bridge opposite the active gage. Thus, any resistance change due to temperature change is common to both and is automatically cancelled.

Strains perpendicular to the gage axis affect the wire in the loops of the grid. This causes the gage to indicate a false axial strain. This is called transverse sensitivity error. Electric resistance strain gages are subject to varying degrees of transverse sensitivity, according to type. The apparent strains indicated by the gage readings must be corrected for this effect. Because Poisson's effect is quite pronounced in certain directions for the case of wood, the transverse sensitivity correction becomes most important for this material. It will be assumed in the equations of the following discussion, that all of the strains are true values that have been corrected for transverse sensitivity. Equations for transverse sensitivity are presented later.

A thorough treatment of the subject of strain gages and gaging methods is given in chapters 5 and 9 of the "Handbook of Experimental Stress Analysis" (4).[2] Many excellent papers concerning electric resistance strain gages may be found in the many volumes of the "Proceedings of the Society for Experimental Stress Anal ysis" (9).

The Problem

The elastic constants for a few species have been published (3). The relationship between these constants and the moisture content and specific gravity of the wood have also been studied. As is the case with all of the other physical properties of wood, there is a great deal of variation in values of the elastic constants of wood, even within species. Therefore, average values for elastic constants cannot be used in a precise analysis of a particular problem. Each problem requires the solution of the elastic constants for the piece of material from which the test model or part is constructed.

Means of evaluating the elastic constants of wood using mechanical gages have been published (3,6). The advantage of electric resistance gages over the mechanical gages is the high sensitivity of the gages resulting in accurate values for the elastic constants. Each division of the strain indicator is 0.00001 inches per inch. Strains can be read to the nearest half division. Such sensitivity is not attained with the mechanical gages ordinarily used in elastic constant determination.

When mechanical gages are used, it is always necessary to measure gage lengths, and such measurements are subject to error. Also specimen dimensions must be measured for constant calculations. For those constants which are very small numerically (thus most subject to error) no physical measurements are required when electric resistance gages are used.

Wood Considered as an Orthotropic Material

In the mathematical expressions which follow, wood is considered to behave according to the stress-strain relations of the theory of orthotropic elasticity (5). Norris (8) and others have demonstrated that this assumption is valid.

The three mutually perpendicular planes, longitudinal (L), radial (R), and tangential (T), are the planes of elastic symmetry according to the above assumption. The primary orthotropic orientation is shown in figure 4. For the general three dimensional

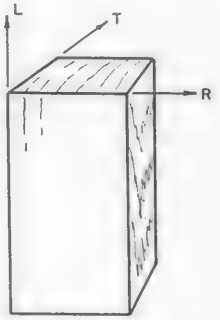

Figure 4.—The primary orientation for wood considered as an orthotropic material.

case there are twelve elastic constants; E_L, E_R, E_T, G_{LR}, G_{LT}, G_{TR}, μ_{LR}, μ_{LT}, μ_{RL}, μ_{TL}, μ_{RT}, and μ_{TR}. Where,

E—Modulus of elasticity for the direction denoted by the subscript.

G—Modulus of rigidity for the plane denoted by the double subscript.

μ—Poisson's ratio for a strain in the direction of the last subscript caused by a normal stress in the direction of the first.

In general, a piece of lumber is not sawn with the respective faces truly radial and tangential, as shown in figure

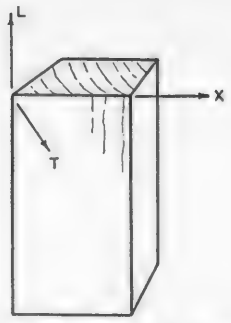

Figure 5.—The orientation for a piece of lumber intermediate between flat and quarter sawn.

4. It is more apt to approximate the situation shown in figure 5. Further, most stress analysis problems are involved with the case of biaxial stress, or stress in a single plane. The problem is then greatly simplified. If LX is designated as the plane of stress, only the five following elastic constants are needed for the solution of the stress analysis problem; E_L, E_X, G_{LX}, μ_{LX}, and μ_{XL}. The notation has the meaning described above.

Test Procedure

General: For the evaluation of the elastic constants there are certain procedures common to the three compression tests required; compression parallel, perpendicular, and at 45° to the grain.

Each specimen is a rectangular prism with a cross section approximately 2 inches square. The length of the specimens is 4 inches. For the compression perpendicular to the grain specimen, where the radius of curvature of the annual rings is rather small, it may be necessary to build up the prism by gluing pieces together. The central section of such a specimen should be a 2 inch cube. The upper and lower portions of the specimen would then be 1 inch long and 2 inches square. Two specimens are shown in figure 6. The first

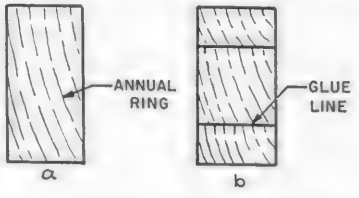

Figure 6.—Solid and built-up compression perpendicular to the grain specimens.

is a solid specimen with long-radiu rings; the second, a glued-up specimen

Tests should be conducted as nearly in agreement with the standard specifications as possible (1).

Gages should be read alternately when continuous loading is used.

Intermittent loading, however, ha proven satisfactory in the experienc

[2] Numbers in parentheses refer to literature cited.

of this laboratory. In this type of test, each gage can be read for every interval of load.

The data are plotted in the form of load versus strain curves. If the resulting plots do not possess definite straight line portions, the test results should not be assumed valid. In the equations that follow, ϵ shall denote normal strain increment corresponding to an abitrary increment of load, P, taken from the straight line portion of the load-strain plot.

It is necessary that the three compression specimens used for the determination of the elastic constants be taken from the same board as is the test model for which the stress analysis is obtained. The best method, when the test model is large enough, is to take the elastic constant specimens from the model itself after it has been tested. These specimens should be taken from a portion as near as possible to the position of the strain gages on the test model itself.

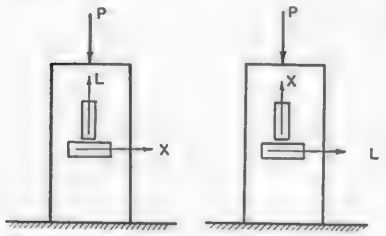

Figure 7.—Gage orientations for compression parallel to the grain specimen.

Figure 8.—Gage orientations for compression perpendicular to the grain specimen.

Moisture content has been shown to have a pronounced effect upon the magnitude of the elastic constants (3). It is essential that all of the specimens be tested at the same moisture content. And this moisture content should be that of the model at the time of test.

Compression Parallel to the Grain: The manner of loading this specimen and the gage position are shown diagrammatically on figure 7. Gages are mounted on both LX planes of the specimen—on opposite faces. Each pair of gages with their axes in the same direction is wired in series. In this manner the effect of any bending will be compensated automatically.

ϵ_L and ϵ_X, corresponding to an arbitrary increment of load, P, are obtained from the load versus strain plots. The subscript for the normal strain indicates the direction of the strain.

The following elastic constants may then be computed.

$$1.\ E_L = \frac{P}{A\,\epsilon_L}$$

$$2.\ \mu_{LX} = \frac{\epsilon_X}{\epsilon_L}$$

where A is the cross-sectional area.

Compression Perpendicular to the Grain: The placement of the gages and the method of loading of this specimen are shown in figure 8. As before, all gages are in pairs and these pairs wired in series.

The strains, ϵ_L and ϵ_X, corresponding to the arbitrarily selected increment of load, P, are obtained from the load-strain graph. The following calculations may then be made.

$$3.\ E_X = \frac{P}{A\,\epsilon_X}$$

$$4.\ \mu_{XL} = \frac{\epsilon_L}{\epsilon_X}$$

Usually, the quantity ϵ_L will be quite small, which may cause the computed value of μ_{XL} to be subject to considerable error. It is well to check the value of μ_{XL} using the following equation (5,7).

$$5.\ \mu_{XL} = \frac{E_X\,\mu_{LX}}{E_L}$$

It is quite possible that the value of μ_{XL} computed from the above relation will be more nearly correct than that obtained from equation 4.

Compression at 45° to the Grain: A special precaution must be taken in this test. As shown is figure 9, the

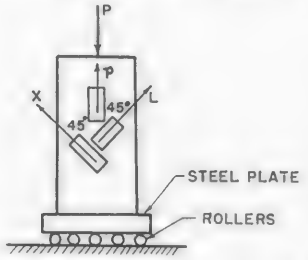

Figure 9.—Sketch of compression 45° to the grain specimen, showing manner of loading and gage positions.

specimen rests upon a steel plate which is separated from the machine bed by a group of steel rollers. If this were not done, the end friction would be sufficient to cause restraint of the shear distortion (8).

As before, each of the gages shown in the figure represents a pair of gages wired in series.

The corresponding values of load and strain increments are taken from the plots. In this test three strains are measured. ϵ_P is the strain in the direction of the load.

From the geometric consideration of the strains for the case of plane stress (7), the following applies, where δ_{XL} is the total shearing strain.

$$6.\ \delta_{XL} = 2\left(\epsilon_P - \frac{\epsilon_X + \epsilon_L}{2}\right)$$

The shear stress, τ_{XL}, may be found from the equations of equilibrium. For this special case of uniaxial compression, we have (10),

$$7.\ \tau_{XL} = \frac{\sigma_P}{2}\sin 2\theta$$

where,

σ_P = normal stress in the direction of the load.

θ = angle between the L and load directions.

In this particular case, $\theta = 45°$, so equation 7 may be written,

$$7'.\ \tau_{XL} = \frac{\sigma_P}{2} = \frac{P}{2A}$$

Thus the modulus of rigidity may be computed, using equations 6 and 7′.

$$8.\ G_{XL} = \frac{P}{4A\left(E_P - \dfrac{\epsilon_X + \epsilon_L}{2}\right)}$$

A Check on the Elastic Constant Values Computed in the First Two Tests: In the case of the 45° to the grain test, the following equations from the theory of orthotropic elasticity apply.

$$9.\ \sigma_L = E_L\left(\frac{\epsilon_L + \mu_{XL}\,\epsilon_X}{1 - \mu_{XL}\,\mu_{LX}}\right)$$

$$10.\ \sigma_X = E_X\left(\frac{\epsilon_X + \mu_{LX}\,\epsilon_L}{1 - \mu_{XL}\,\mu_{LX}}\right)$$

The values of E_L, E_X, μ_{LX} and μ_{XL}, as computed from the compression parallel and perpendicular to the grain, when substituted into these relations, should satisfy the equalities.

Correcting for Strain Gage Transverse Sensitivity

The following correction equations were derived by R. Baumberger and F. Hines (2).

$$11.\ \epsilon_L = \frac{(1 - \mu_0 K)(\epsilon_L' - K\,\epsilon_X')}{(1 - K^2)}$$

$$12.\ \epsilon_X = \frac{(1 - \mu_0 K)(\epsilon_X' - K\,\epsilon_L')}{(1 - K^2)}$$

where,

ϵ_X, ϵ_L = true strains in the L and X directions.

ϵ_X', ϵ_L' = apparent strains in the L and X directions.

$\mu_0 = 0.285$. (Poisson's ratio for the manufacturer's strain gage calibration bar).

K = gage correction factor (which may be obtained from the manufacturer of the gages used).

Serious error may be involved by not correcting strain readings, as indicated in the following example. In an experiment using SR–4 A–5 gages (for which K=0.034) the apparent strains were $\epsilon_L' = +600$ microinches per inch and $\epsilon_X' = +15$ microinches per inch. The + sign indicates tension.

The true strains would be, to sliderule accuracy,

$$\epsilon_L = \frac{(1 - 0.285 \times 0.034)(600 - 0.034 \times 15)}{[1 - (0.034)^2]} = +599$$

$$\epsilon_X = \frac{(1 - 0.285 \times 0.034)(15 - 0.034 \times 600)}{[1 - (0.034)^2]} = -5$$

Note that the apparent strain in the X direction was tensile, whereas the true strain was actually compression as indicated by the negative sign.

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Strain Distribution in Maple Glue Block Shear Specimen as Indicated by a Brittle Lacquer[1]

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Discusses an exploratory study of the strain distribution in a standard maple glue block shear specimen. Special emphasis is placed on a relatively new technique for obtaining a qualitative and, to a limited extent, a quantitative measure of strain distribution.

AN EXPLORATORY STUDY of the strain distribution in the standard maple glue block shear specimen was made employing a brittle lacquer strain-indicating coating. The configuration of the strain pattern and the manner in which it formed during a loading cycle indicated that high stress concentrations exist at the reentrant corners of the test specimen, and that tensile stresses of varying direction and magnitude act on the plane of the glue joint. The technique of application of the brittle lacquer to the wood surface also is discussed.

[1] A contributed paper.

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Introduction

As part of a continuing research project in the gluing of wood being conducted at the State University of New York, College of Forestry, an investigation into the strain distributions in the conventional glue joint test specimens has been initiated. In any type of test specimen, it is imperative to know which particular strength properties of the wood and the glue influence the result of the test. For instance, the two most commonly used test specimens for evaluating the quality of a glue bond are the maple block shear test and the plywood tension shear test given in A.S.T.M. Specifications D–805–52 (1).[2] In the maple block shear test, the test specimen is cut to a specified size and shape from two face-glued boards, and a compression load is applied as shown in Figure 1. The manner of loading is such as to exert a shear stress in the plane of the glue joint, and the factors assumed to be under test are:

1. Shear strength of the glue film
2. Shear strength of the wood-glue interface
3. Shear strength of the wood parallel to the grain

[2] Numbers in parentheses refer to literature cited.

Similarly, in the plywood test specimen, the size, shape and method of loading are assumed to provide a test specimen which will subject the glue joints and the core veneer to shear stresses under tensile loading.

These test specimens have been examined by several investigators *(3, 5, 6, 7, 8, 12)* in an attempt to account for the extreme variability in breaking load often encountered during testing. From a practical standpoint, it is extremely difficult to obtain a condition of pure shear loading, and in both of the test specimens under discussion the existence of tensile, compressive and cleavage stresses has been accepted to occur.

The results of the glue block shea and plywood tension shear tests ar usually interpreted on the basis that shear load is uniformly distribute across the area of the glue joint. Th shear stress at the breaking load is ob tained by dividing the total load b the area on which it acts. In many in stances, this *average* stress has ver little significance since failure is deter mined by the maximum stress and no the average stress. To further compli

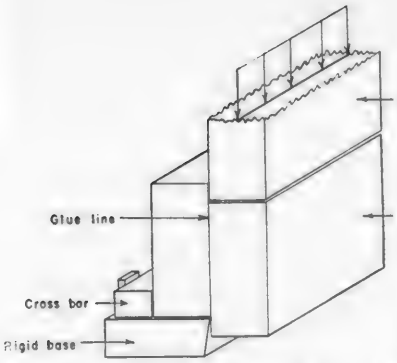


Figure 1.—Diagram of the block shear test loading tool.

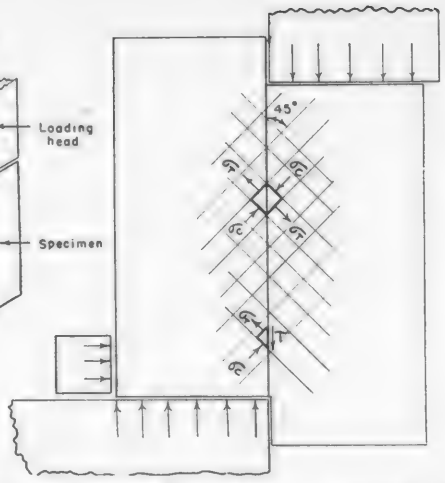


Figure 2.—The theoretical distribution of normal tensile stresses (σ_T) normal compression stresses (σ_c) and shear stress (τ) in the plane of the glue joint of the maple glue block shear specimen for the case of pure shear.

cate the situation, it is necessary to consider the nature, direction and magnitude of the stresses causing failure with respect to the orientation of the wood fibers and the glue joint. The glue joint may not form the plane in which the maximum shear stress occurs, nor does failure necessarily occur perpendicular to a maximum principal stress. Failure may take place in some weaker plane of the wood where a lower stress exists.

The existence of stresses other than pure shear in the plane of the glue joint, and the effects of mis-machining of the test specimen, mis-alignment of the test grips or fixture, and slope of grain and anatomy of the wood therefore require analysis with a greater rigor than that provided by a simple measure of the breaking load. In the sections to follow, the exploratory work accomplished to date will be discussed with special emphasis being placed on a relatively new tool of research available for investigation of strain distribution in wood and wood-glue combinations. This new technique employs a brittle-lacquer coating which when applied to the surface of a test specimen provides a "picture" of the principle strains in the specimen. From the crack pattern formed during the test, a qualitative and to a limited extent a quantitative measure of stress distribution may be obtained.

The Brittle Lacquer

The brittle lacquer employed in this study is known as "Stresscoat" and is a product of the Magnaflax Corporation. This material has the property of cracking under tensile load. The principal tensile strain is perpendicular to a crack at any point in the crack pattern. Although it has been used widely in stress analysis studies of isotropic engineering materials, it has been applied to wood or wood-glue structures in only a few isolated investigations *(9, 10)*. Stresscoat is available in a "kit" form which contains not only the brittle lacquer, but also a dye etchant to color the cracks, an emulsifier to remove excess dye and a number of other accessories including a compressor-spray gun combination for applying the coatings and a calibration set-up for determining the strain sensitivity of the brittle lacquer at the time of test.

The technique of application of the lacquer to the surface of the wood test specimens used in this study was, in general, similar to that outlined in the manufacturer's instruction manual *(2)* for conventional use on metal surfaces. A brief outline of this procedure is as follows:

1. Prepare test surface by removing dirt, grease and the like using a highly volatile solvent.
2. Apply undercoating lacquer and allow to dry for 15 minutes.
3. Select strain-indicating coating upon basis of temperature and humidity conditions existing at time of test.
4. Apply strain-indicating coating of uniform thickness in the range from 3 to 6 mils and allow to dry from six hours to overnight before testing.

As this exploratory study progressed it became increasingly evident that several changes were required in order to improve the film characteristics when the brittle lacquer is applied to wood:

Preparation of the Test Specimen: Jointing or planing the wood provided the smoothest and cleanest surface for application of the coatings. Sanded and sawn surfaces resulted in rougher appearing surfaces especially when the undercoating lacquer was applied. This roughness was due to the loose or torn wood fibers on the surface and to the grit or tooth marks left by the machining operation. The aluminum undercoating lacquer emphasized these surface irregularities.

Application of the Undercoating Lacquer: The aluminum undercoating provides a uniform background for viewing the cracks which form in the strain indicating brittle lacquer. On wood surfaces, it serves the added purpose of establishing a moisture barrier which minimizes the occurrence of stresses in the wood surface due to gain or loss of moisture. However, the fifteen minute drying period specified by the manufacturer was found to be insufficient. After this short drying period, large bubbles formed in the brittle lacquer film when it was sprayed onto the aluminum undercoating. Also, in several instances, small flecks of aluminum rose to the top of the brittle lacquer coating. Apparently, the solvent action of the carbon disulfide vehicle used in the brittle lacquer is sufficient to release air which may be entrapped in the wood fibers beneath the aluminum layer and to solvate the aluminum undercoating to the extent that some particles of aluminum are free to rise to the surface of the brittle lacquer. A drying time of at least four hours and preferably overnight was indicated as being necessary to prevent these difficulties.

Selection of the Strain-indicating Brittle Lacquer: A series of twelve or more mixtures of the brittle lacquer are available for use depending upon the temperature and relative humidity conditions encountered during testing. A chart is provided by the manufacturer to permit selection of the proper mixture. In the present investigation, mixture ST-1206 was employed in a majority of the early test runs for use at a temperature of 75° F and a relative humidity of 40 to 50 percent on hard maple test specimens. Large drying cracks frequently formed in the brittle film during drying, and although they are readily separated from the strain-indicating cracks, they sometimes make it difficult to obtain clear photographs of the crack pattern. Several other mixtures were examined and ST–1200 showed the least tendency to form these drying cracks under the conditions given above.

The manufacturer recommends drying the brittle lacquer at an elevated temperature in the range from 100° to 150° F, in order to

minimize the occurrence of these drying cracks. However, it is impossible to treat wood samples in this manner since drying stresses will be established in the wood which may cause considerable distortion of the test specimen and will result in cracks being formed in regions of tensile stress.

Although all of the spraying and drying operations were carried out in a controlled temperature and relative humidity room set for 75° F and 50 percent relative humidity, it was necessary to load the specimens in a universal testing machine located in a laboratory where no control of the atmospheric conditions was possible. A temperature of 90° F and 70 to 80 percent relative humidity existed at times, and under these conditions the brittle lacquer was completely desensitized. The usual remedy is to use a more sensitive lacquer (higher coating number), but in the present study, no success was attained even with ST-1210, the highest numbered coating on hand. An attempt was made to spray the test specimens in the testing laboratory where the relatively high temperature and humidity conditions prevailed. However, the rapid evaporation of the highly volatile lacquer solvent lowered the temperature of the film below the dew point and moisture condensed into the lacquer film. Under normal temperature and humidity conditions good results were obtained with the brittle lacquer specified by the manufacturer for the particular conditions encountered.

Application of the Strain-indicating Coating: The use of a spray gun is recommended by the manufacturer for application of the brittle lacquer to the test surface. The high volatility of the lacquer solvent makes brushing or dipping very difficult, but the principal advantage obtained by spraying is that a large number of small air bubbles are introduced into the lacquer film increasing the regularity and dependability of the strain patterns. Repeated attempts were made to establish a standard spraying procedure in order to obtain a method for replicating the thickness of the coating. The number of passes, the distance from the spray-gun to the test surface and the air pressure used in spraying were varied and the thickness of wet lacquer film was measured with an Interchemical Wet Film Thickness Indicator *(4)*. The results of this limited study indicated that no fixed value for any of these variables could be established. In general, a series of from four to eight passes over the test surface with the spray-gun held six to eight inches from the work produced a satisfactory film. However, the best criterion of uniformity of film thickness on an individual sample, and consistency of thickness between samples, was the color of the lacquer film. At the start of a spraying operation the lacquer appears transparent and almost colorless. After several passes with the spray-gun it becomes yellow-green in color. On metal surfaces the recommended film thickness is in the range from 0.003 to 0.006 of an inch and the color is usually yellow-green and retains a transparent nature. On the wood test specimens employed in this investigation, a film thickness of 0.008 to 0.015 of an inch produced the clearest crack patterns. This range of film thickness is reached when the wet lacquer film becomes opaque and greenish–tan in color. The opacity is due to powdering of the lacquer as it is deposited on the test surface, In many instances, as the film dried it regained its transparent appearance but remained tan–green in color. A drying period of at least six hours is recommended by the manufacturer, and in the present study the brittle lacquer was allowed to dry for twenty-four hours in the air conditioned room before removal to the testing laboratory.

Analysis of the Strain Pattern

As an example of a strain analysis employing the Stresscoat technique, a series of maple glue block shear specimens were coated and tested. The choice of this test specimen was based upon its widespread use as a means of determining the adhesive properties of wood glues. As shown by the photoelastic studies of Coker and Coleman *(7)* the stress distribution in a xylonite model of a solid wood shear test specimen is quite complicated. Based upon their work, a report *(3)* was made by the Committee on Mechanical Tests of Timbers, Department of Science and Industrial Research of Great Brit,-ain which stated "- - - - The shear stresses along the grain are very far from being uniformly distributed and are accompanied by cross-grain tensile stresses of considerable magnitude. Since the tensile stresses are probably the primary cause of failure the standard test piece and its methods of loading are unsuitable for the measurement of shear strength".

The stress distribution in a glue block shear specimen is equally as complex as the solid wood shear test and only a qualitative determination of the strain pattern was attempted in this initial study. The glue block shear specimens were prepared from hard maple boards carefully matched for density and grain alignment. The wood was conditioned to a moisture content of approximately eight percent and face-glued in a radio frequency press. After a reconditioning period of two weeks, the edges and faces of the boards were surfaced on a jointer and the shear specimen cut with a carbide-tipped saw. Special care was taken in machining the end grain surfaces in order to minimize the possibility of variations in the strain pattern due to mis-machining. The test specimens were returned to the air conditioned room for storage and subsequent spraying and drying of the brittle lacquer.

A 50,000 pounds capacity Riehle testing machine with a Tinius Olsen shear testing tool was used to apply the compressive load to the coated specimens. The load-bearing end grain surfaces of the specimens were covered with powdered graphite to minimize frictional restraint and to aid in detecting the actual bearing areas. Load was applied continuously at the standard rate of 0.015 of an inch per minute up to a total load of 7000 pounds. The dye etchant was applied to the coated surfaces in order to preserve the outline of the tensile crack pattern formed during the loading cycle. Two applications of the dye were made and wiped off, and then a third application of dye was made and allowed to remain while the load was released as rapidly as possible. Due to the elastic spring back in the wood upon release of the load, the brittle film was subjected to tensile loading. In this way, the crack pattern corresponding to the compressive stress distribution was obtained.

A number of interesting observations can be drawn from the strain patterns on the maple glue block shear specimens. First of all, if a uniform stress distribution existed along the entire glue joint, a system of cracks should have appeared simultaneously over this region when the strain threshold of the brittle lacquer was reached. Instead, cracks occurred near the reentrant corners at very low loads indicating that high stress concentrations existed in these areas. Secondly, if the glue joint had been subjected to pure shear stress, the tensile and compressive cracks would have formed angles of 45 degrees with the glue line over the entire test section. See Figure 2.

By neglecting the influence of strain gradients and assuming that the strain threshold of the brittle lacquer remains constant, a relative measure of the concentration of stress near the reentrant corners was obtained by forming the ratio of the load required to form a crack in the central region to the load

required to form a crack near a reentrant corner, It is imperative to realize that this index of concentration of stress is based upon the formation of cracks representing the principal tensile strains, and does not account for the effects of the compressive and shear stresses which exist at every point along the glue line. As shown in Table 1, rather high concentrations of stress may occur at the reentrant corners. The variability in these indices indicates the difficulty encountered in obtaining the same strain distribution in different specimens or even on opposite faces of the same specimens.

Table 1.—LOAD IN POUNDS TO CRACK BRITTLE LACQUER AT SPECIFIED POINTS ALONG GLUE JOINT AND RATIOS OF THESE LOADS AS AN INDEX OF CONCENTRATION OF STRESS

Sample No.	Left side of test specimen			Right side of test specimen		
	A. Initial crack at corner	B. Initial crack in central region	Ratio: B/A	A. Initial crack at corner	B. Initial crack in central region	Ratio: B/A
1	390	1780	4.6	390	1250	3.2
2	80	1860	23.3	80	1860	23.3
3	130	1960	15.1	420	3960	9.4
4	100	1370	13.7	360	2870	8.0
5	100	1420	14.2	520	2210	4.3

Any deviation in the direction of the principal strains from the ideal case of 45 degrees indicate that normal components of stress act on the plane of the glue joint. Thus, for any angle, Θ, between 0 and 45 degrees, a proportion of the maximum shear stress exists, and is accompanied by normal stress components (11). The angles between the actual cracks (tensile or compressive) and the plane of the glue joint given in Figures 3 and 4 were obtained by direct measurement from enlarged (4x) pictures of the crack patterns as shown in Figure 5. The fact that these angles differ markedly in many instances from the ideal case of 45 degrees indicates that neither a pure nor uniform shear stress exists in the plane of the glue joint, but rather that normal components of stress varying in magnitude and direction are imposed on the glue joint. No attempt has been made to evaluate the magnitude of the stresses perpendicular to the glue joint since the required information is not readily provided by the brittle lacquer technique.

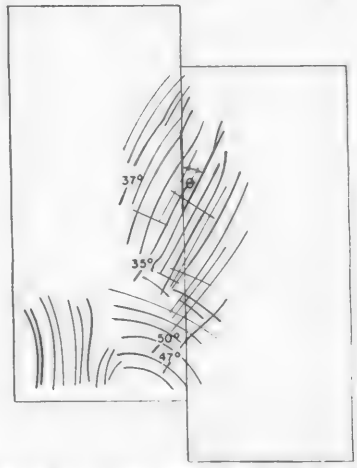
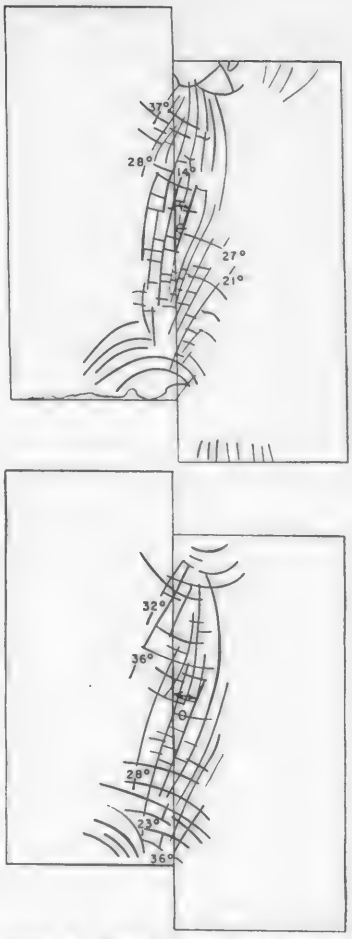


Figure 3.—Crack pattern on maple glue block shear specimen showing the angle θ between individual cracks and the plane of the glue joint.

Since neither pure nor uniform shear stress exists in the plane of the glue joint, several factors must be considered when evaluating the results of a maple glue block shear test. These are:

1. The shear stress computed by dividing the load by the area of the glue joint is an average shear stress. The occurrence of strain cracks at very low loads near the reentrant corners of the shear block indicates high stresses in these areas. Failure will be initiated in these regions of maximum stress, and a stress concentration factor should be determined in order to establish the magnitude of stress when rupture occurs.

2. The presence of stress components normal to the plane of the glue joint and normal to the longitudinal grain direction in the wood imposes stresses which must be resisted by the cohesive strength of the glue and the tensile strength of the wood-glue interface and by the wood itself. Since the tensile strength of the interface and of the wood perpendicular to the grain are considerably less than the respective shear strengths, failure may occur due to tensile stresses instead of shear stress.



Figures 4A and B.—Crack pattern on opposite sides of maple glue block shear specimen showing angle θ between individual cracks and plane of glue joint.

Figure 5.—Photograph of crack pattern on maple glue block shear specimen.

3. The accuracy of machining of the end grain load-bearing surfaces and the uniformity of the grain slope in the individual test specimens will affect the reproducibility of the strain distribution depicted by the crack pattern in the brittle lacquer. In the present study, even though extreme care was taken to machine the end surfaces smoothly and accurately, they were not loaded over the entire bearing area. The powdered graphite dusted onto these surfaces indicated that the loading was confined to a 5/16ths of an inch strip adjacent to the glue line. By virtue of the geometry of the test specimen, a couple is established as shown in Figure 6, which, in turn, causes the specimen to rotate in the loading fixture. Any play or excessive tolerance in the fixture will emphasize the effect of this bending moment. The net effect of the tensile stresses described above and of this bending moment is to create cleavage stresses which are at a maximum at the corners of the test specimen adjoining the glue line. These stresses may also prove to be a major factor in the initiation of failure in the glue joint or in the wood adjacent to the glue line.

Conclusions

This exploratory study of the use of Stresscoat for the analysis of strains

in the maple glue block shear specimen revealed the following:

1. Stresscoat, a strain-indicating brittle lacquer, may be applied to wood with but slight modifications in its application procedure. 2. A qualitative "picture" of the principal strains may be obtained, but due to the anisotropic nature of wood, quantitative measures of the principal stresses are difficult to obtain. 3. The variation in the shear stress across the plane of the glue joint and the presence of normal stress components indicate that further knowledge must be obtained to permit more valid interpretation of the results of this test.

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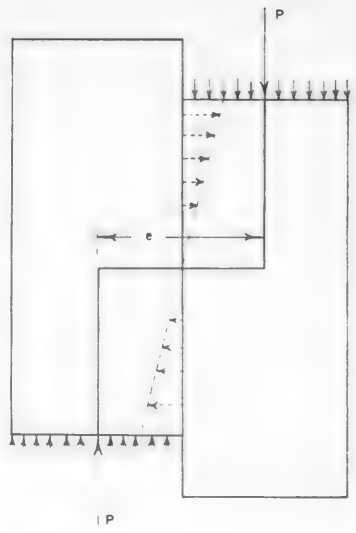

Figure 6.—Distribution of stresses normal to the plane of the glue joint due to the couple P x e which exists in the maple glue block shear specimen.

Performance of Laminated Preservative-Treated Railroad Bridge Stringers[1]

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Describes what is believed to be the first attempt to laminate railroad bridge stringers from creosoted and Wolmanized treated lumber and also discusses the performance of these stringers in service.

SEVERAL INSTALLATIONS of laminated railroad bridge stringers treated with creosote after gluing have been put in service during the last decade. Production of such members by gluing of treated lumber, however, has not to date been done to an appreciable extent. Gluing of treated wood has definite advantages in that it may permit the production of large members thoroughly impregnated. Thin laminations by proper choice of materials, can be given practically complete penetration of preservative chemicals; this, as a rule, is not possible with large timbers. When members, because of their shape and size, do not lend themselves to treatment, laminating of treated material is the only way of producing adequately treated structures.

Treating, Gluing, and Curing

The laminations were produced from No. 1 common southern yellow pine. The lumber was pressure-treated with Wolman salts by the full-cell process to a dry salt retention of 0.3 pounds per cubic foot or with creosote by the Rueping process to a retention of 8 pounds per cubic foot. The lumber that was to be treated with creosote was conditioned by steaming for nearly 9 hours at 20 pounds gage pressure (approximately 259° F.) followed by a 2-hour vacuum prior to treatment. The creosoted material appeared "dry", and no bleeding was apparent after surfacing. The gluing and treating was done by the American Lumber and Treating Company, Gainesville, Fla., in February and March 1946. Four other stringers were laminated of untreated material and treated after gluing.

[1] Presented to the Subject Matter Committee on Preservatives at the annual meeting of the Forest Products Research Society in Grand Rapids, Michigan, May 5, 6, and 7, 1954.

[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

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Table 1.—TREATING, GLUING, AND CURING DATA

Stringer number	Size	Preservative and retention	Glued before or after treating	Approximate spreading time[1]	Approximate clamping time[1]	Curing time	Curing temperature
		Lb. per cu. ft.		Min.	Min.	Hrs.	° F.
1	7 in. x 14 in. x 14 ft.	0.3 lb. Wolman salts[2]	Before	30	35	11	160
2	do.	8 lb. creosote	Do.	13	37	11	160
3	do.	0.3 lb. Wolman salts	Do.	14	40	11	160
4	do.	8 lb. creosote	After	17	35	11	160
5	do.	0.3 lb. Wolman salts	Do.	12	40	12	160
6	do.	0.3 lb. Wolman salts	Do.	12	48	12	160
7	do.	8 lb. creosote	Do.	15	43	11	160
8	do.	0.3 lb. Wolman salts	Before	21	76	11	160
9	7 in. x 14 in. x 21 ft.	0.3 lb. Wolman salts	After	(3)	(3)	24	155
10	do.	0.3 lb. Wolman salts	Do.	(3)	(3)	24	155
11	do.	0.3 lb. Wolman salts	Do.	(3)	(3)	60	132
12	do.	0.3 lb. Wolman salts	Do.	(3)	(3)	60	132
13	do.	8 lb. creosote	Do.	(3)	(3)	12	160
14	do.	8 lb. creosote	Do.	(3)	(3)	12	160
15	do.	8 lb. creosote	Do.	(3)	(3)	12	160
16	do.	8 lb. creosote	Do.	(3)	(3)	12	160
17	do.	0.3 lb. Wolman salts	Do.	25	20	18	160
18	do.	0.3 lb. Wolman salts	Do.	25	25	18	160
19	do.	8 lb. creosote	Do.	25	20	9	160
20	do.	8 lb. creosote	Do.	25	20	9	160
21	do.	0.3 lb. Wolman salts	Do.	25	25	8	160
22	do.	0.3 lb. Wolman salts	Do.	25	25	8	160
23	do.	0.3 lb. Wolman salts	Do.	25	25	12	160
24	do.	0.3 lb. Wolman salts	Do.	25	25	12	160
25	do.	8 lb. creosote	Do.	25	25	5	190
26	do.	8 lb. creosote	Do.	25	25	5	190
27	do.	8 lb. creosote	Do.	25	25	12	160
28	do.	8 lb. creosote	Do.	25	25	12	160

[1] The total assembly time is the sum of the spreading and clamping time (30 min. + 35 min. etc.).

[2] Tanalith.

[3] Open assembly 0-5 min. Closed assembly about 1 hour before clamping.

Both treated and untreated lumber was kiln dried before final surfacing for gluing. The moisture content of the lumber at the time of gluing averaged from 12 to 15 percent. All laminations were surfaced a few hours before they were glued. The creosoted material showed no bleeding during surfacing and glue spreading.

Gluing and curing conditions used are shown in table 1. Six different resorcinol glues were used. They were spread at a rate of about 60 pounds per thousand square feet of joint area. Gluing pressure was applied by means of retaining clamps spaced on 8-inch centers. The clamps had a pressure-equalizing top member. The pressure was checked by means of a torque wrench, and approximately 175 pounds per square inch was applied. The curing was carried out in a forced-circulation dry kiln equipped with automatic temperature and humidity control. The curing time and temperature used for each stringer are shown in table 1; a 10° F. wet-bulb depression was used.

Preliminary Tests

A 9-inch sample from each stringer was sent to the Forest Products Laboratory for dry shear-block tests and accelerated soaking-drying delamination tests.

Dry Shear Test: At least 9 standard shear-block specimens from each sample were prepared and tested. The average results are shown in table 2

Accelerated Soaking-Drying Delamination Test: One 3-inch long section from each sample was subjected to a cyclic soaking-drying test. Essentially, this test was similar to the test of the American Society for Testing Materials, "Integrity of Glue Joints in Laminated Wood Products for Exterior Service," A.S.T.M. Designation D1101–50T, except that the test required 21 days instead of 12 days. Results of this test are shown in table 2.

Table 2. — RESULTS OF DRY SHEAR-BLOCK TESTS AND ACCELERATED CYCLIC SOAKING–DRYING TESTS ON SECTIONS MADE OF CREOSOTED WOLMANIZED, AND UNTREATED SOUTHERN YELLOW PINE

Beam number	Treatment of lumber before gluing	Shear strength	Wood failure	Delamination[1]
		P.s.i.	Percent	Percent
3	Untreated	2 1,732	93	2.8
8	Untreated	1,866	81	1.5
1	Untreated	1,788	85	1.2
2	Untreated	2,069	86	1.9
Ave.		1,864	86	1.9
6	Wolmanized	1,755	72	.2
23	Wolmanized	1,940	73	.9
24	Wolmanized	1,706	83	.9
22	Wolmanized	1,995	60	5.2
21	Wolmanized	2,048	91	2.7
5	Wolmanized	1,778	81	2.8
17	Wolmanized	1,829	87	5.6
18	Wolmanized	1,666	89	2.6
9	Wolmanized	1,693	79	6.2
11	Wolmanized	1,836	85	4.6
10	Wolmanized	1,860	81	.8
12	Wolmanized	1,914	84	1.4
Ave.		1,835	80	2.8
27	Creosoted	1,531	75	1.1
28	Creosoted	1,685	75	.3
26	Creosoted	1,570	79	.0
7	Creosoted	1,409	53	12.6
25	Creosoted	1,576	75	11.7
19	Creosoted	1,514	91	.1
20	Creosoted	1,962	91	.3
13	Creosoted	1,562	88	.4
15	Creosoted	1,625	97	.1
4	Creosoted	1,494	54	9.8
14	Creosoted	1,666	93	.6
16	Creosoted	1,656	98	.3
Ave.		1,582	91	3.1

[1] Amount of open glue joints on end-grain surfaces of one 3-inch section after 3 accelerated soaking-drying cycles.

[2] Each value is the average of at least 9 tests.

Note: Beams 3, 8, 1 Wolmanized after gluing; beam 2 Creosoted

Results of Preliminary Tests

Results of the shear-block tests are shown in table 2. Each value given is the average of at least 9 test specimens from each stringer. Figure 1 and 2 show broken shear-block specimens from some of the stringers.

Shear strength and the percentage of wood failures obtained with the untreated material (treated after gluing) appeared satisfactory, which indicated adequate control of the gluing process. In general, the material that was Wolmanized before gluing also had high strength values and a high percentage of wood failures. For specimens from 12 stringers made of Wolmanized material, the average shear strength was 1,835 p.s.i., and the percentage of wood failure was 80 percent, as compared to 1,864 p.s.i. and 86 percent for specimens from 4 stringers made of untreated material. The lowest average percentage of wood failure for a single section made of Wolmanized material was 60 percent.

The specimens from the stringers made of creosoted material did not produce the uniformly high strength values that were found with the Wolmanized or untreated material. The average strength for specimens from 12 creosoted stringers was 1,582 p.s.i., as compared to 1,835 for the Wolmanized and 1,864 p.s.i. for the untreated material.

No data were obtained on the specific gravity of the wood in the three groups of material, and no matching was attempted. Hence, a direct comparison of shear strength is not valid. The steam conditioning, which preceded the treatment with creosote, however, would tend to reduce the strength of the wood. No data on the effect of steaming on shear strength of wood are available at the Forest Products Laboratory; therefore, the reduction in shear strength from that cause could not be predicted. Tests on thin softwood specimens have shown, however, that steaming for 9 hours at 259° F. may reduce some strength properties 20 percent or more.[3] It appears reasonable to believe, therefore, that at least some of the difference in shear strength of steamed and unsteamed wood may be due to such treatment.

The wood failures were high for the creosoted material except in stringers No. 4 and No. 7, which developed 54 and 53 percent, respectively. The broken shear specimens from these two stringers are shown in figure 2. Figure 2 also shows specimens from stringers number 14 and 28, creosoted specimens that gave high percentages of wood failures.

[3] "Effect of Steaming on the Strength of Wood," by J. D. MacLean, AWPA Proceedings, 1953.

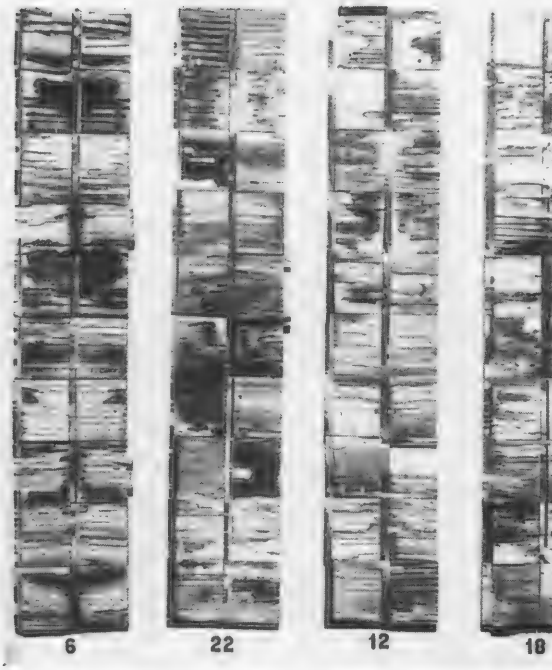


Figure 1.—Broken shear blocks from stringers number 6 and 22 that had some of the lowest percentages of wood failures, and from 12 and 18 that had some of the highest percentages of wood failures.

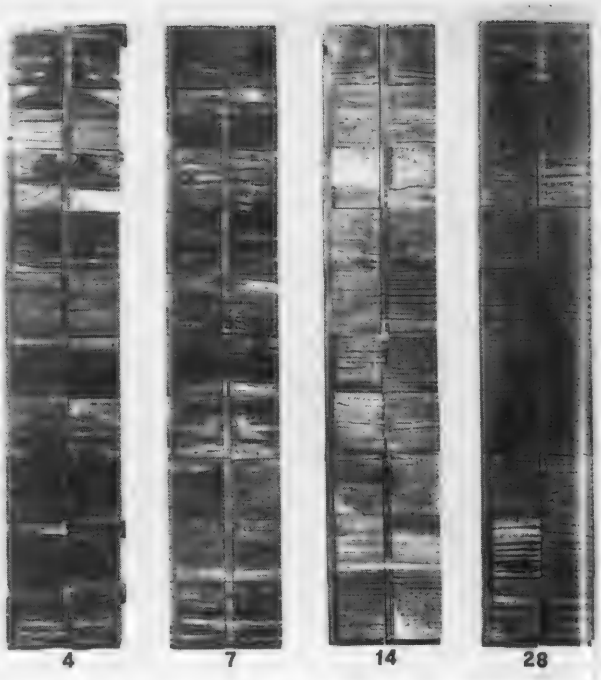


Figure 2.—Broken shear blocks from stringers number 4 and 7 that developed mediocre and erratic wood failure values, and from 14 and 28 that gave uniformly high wood failures.

Figure 3.—Three-inch section of stringer that was treated with Wolman salts before the laminations were glued. After three cycles of accelerated soaking and drying, this section developed the greatest amount of delamination of any section made of Wolmanized material. It amounted to only about 6 percent, however, which is not considered serious.

The results of the accelerated soaking-drying delamination test are shown in table 2. In general, the delamination values were low, which would indicate adequate glue bonds, except in stringers number 4, 7, and 25. The maximum delamination developed in any section, however, was 12.6 percent, which is only slightly more than the delamination permitted in current Navy specifications for laminated material.

Figures 3 and 4 show sections from the stringers made of Wolmanized material, and figures 5, 6, and 7 show sections made of creosoted material. The photographs were taken after the completion of the accelerated cyclic test. The appearance of the sections made of Wolmanized material indicates adequate glue bonds, even for the section that developed the most delamination (fig. 3). The checks in the wood are more predominant than the open glue joints. Of the creosoted sections, specimens No. 7 and No. 25 developed slightly more delamination than is usually regarded acceptable for material intended for exterior service. The remainder of the specimens made of creosoted material showed high resistance to delamination. This indicates that adequate glue bonds can be obtained with resorcinol glues on creosoted yellow pine, where the treatment is not sufficiently heavy to cause bleeding in subsequent surfacing and gluing operations. The data also indicate that southern yellow pine treated with Wolman salts can be glued satisfactorily with resorcinol resin glues, under adequate control of the gluing process.

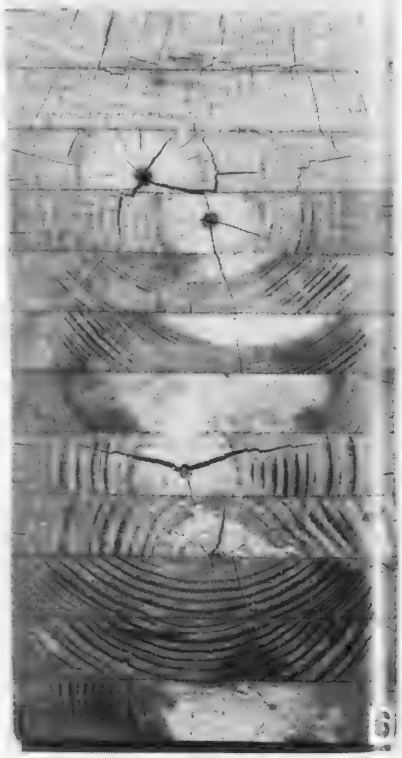


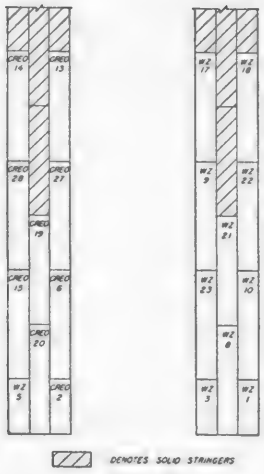
Figure 4.—Three-inch section of stringer that was treated with Wolman salts before the laminations were glued. After three cycles of accelerated soaking and drying, this section was practically free from open glue joints.

Figure 5.—Three-inch section of stringer that was treated with creosote before the laminations were glued. After three cycles of accelerated soaking and drying, this section developed the highest percentage of delamination of the entire group of 28 sections tested.

Figure 6.—Three-inch section of stringer that was treated with creosote before the laminations were glued. After three cycles of accelerated soaking and drying, this section showed 9.8 percent delamination when tested.

Figure 7.—Three-inch section of stringer that was treated with creosote before the laminations were glued. The section was made with the same glue as the section shown in figure 6 but was almost entirely free from delamination. Compared with figure 6, the higher percentage of summerwood exposed on the gluing surfaces in that section may be a partial explanation of the difference in the quality of the glue bonds.

Figure 9.—Side view of railroad bridge over Palmer River, Tampa, Fla. showing laminated stringers.



Installation of Stringers in Railway Bridge

In the summer of 1949, 20 of the 28 stringers glued were installed by the Atlantic Coast Line Railroad in a bridge over the Palm River in East Tampa, Florida. The particular stringers chosen were selected because their length was acceptable to the railroad. Location of the laminated stringers in the bridge is shown in figures 8 and 9.

Figure 8.—Diagram showing location of stringers in the south end of the Atlantic Coast Line Railroad Bridge over the Palm River, Tampa, Fla.

Performance of Stringers in Service

When the stringers were examined in 1952, they all appeared to be in good condition. They were again examined in March 1954 by J. L. Stone, roadmaster of the Atlantic Coast Line Railroad Company, who reported that the stringers were in excellent condition. Since deterioration or delamination of glue joints under outdoor exposure generally develops at the greatest rate during the first year or two of exposure, it would indicate that these stringers can be expected to give satisfactory service for many years.

Distribution of Pentachlorophenol in Pressure and Non-Pressure Treated Douglas Fir Crossarms[1]

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A study was made to determine the relative value of pressure and non-pressure methods of treating Douglas fir crossarms with pentachlorophenol particularly with regard to the relative retentions of preservative attained in specific portions of the arms. Pressure-treated arms were found to have higher preservative retentions adjacent to the pin and bolt holes and in the less accessible portions of the arms. Non-pressure-treated arms were found to have higher retentions in the incised surfaces. Although the preservative penetrated the arms from end to end in the case of both treatments, the variation of pentachlorophenol retentions found between similar sections of pressure-treated arms was markedly less than that found between similar sections of non-pressure-treated arms.

OVER THREE MILLION crossarms were treated in the United States in 1952 for telephone, telegraph, and electric power lines. Of these, 1,380,000 were Douglas fir arms treated with pentachlorophenol, about two-thirds of this number being pressure-treated and one-third non-pressure-treated[2]. The present study was made to determine the relative value of these two methods as they are currently used in the treatment of Douglas fir crossarms[3] particularly with regard to the relative retentions of the preservatives attained in specific portions of the arms. Such information is of value in the appraisal of the relative merits of the two treatments for particular crossarm service requirements. Based on personal experience in particular service applications, some users prefer high relative retentions in the end grain exposed at the crossarm ends and pin and bolt holes and some prefer a more even distribution of preservative throughout the entire arm.

Description of Crossarms Studied

The pressure-treated crossarms studied consisted of six 8-ft x 3-¼ in. x 4-¼ in. Douglas fir crossarms taken from a total shipment of 2280 treated arms. These 2280 arms were treated in two batches and no assignment of the six arms can be made with regard to the particular batch from which they were derived. The arms were picked at random except that only those arms having 100 per cent heartwood were used. They had been incised on all four planed surfaces prior to treatment.

The treating procedure for the pressure-treated crossarms is given in Table I. As the data indicate, the method of treatment used varied somewhat from the procedure normally used in pressure-treating wood products in that no initial air or final vacuum was utilized. This method is quite common, however, among companies treating fir crossarms. The average retention of preservative was 6.03 lb/cu ft calculated from gage readings. The specific gravity of the oil used in preparing the preservative solution waes 0.978, 60/60 F, and the pentachlorophenol content of the treating solutions was 5.15 per cent by weight.

The non-pressure-treated crossarms examined consisted of six 8 ft x 3-¼

[1] A contributed paper.
[2] Proceedings, American Wood Preservers Assoc. 49; 291 (1953).
[3] The comparison made in this paper is, of course, limited. The specific treating cycles used for these crossarms (Table I) are typical but do not include the many variations possible in both the pressure and non-pressure treatments.

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Wanda Pretti-Pavletta is an engineer, works primarily in field of analytical chemistry, including wood preservative studies. She studied in Poland prior to World War II and during first occupation by Russian troops, received M.S. at University of Munich during Allied occupation following the war.

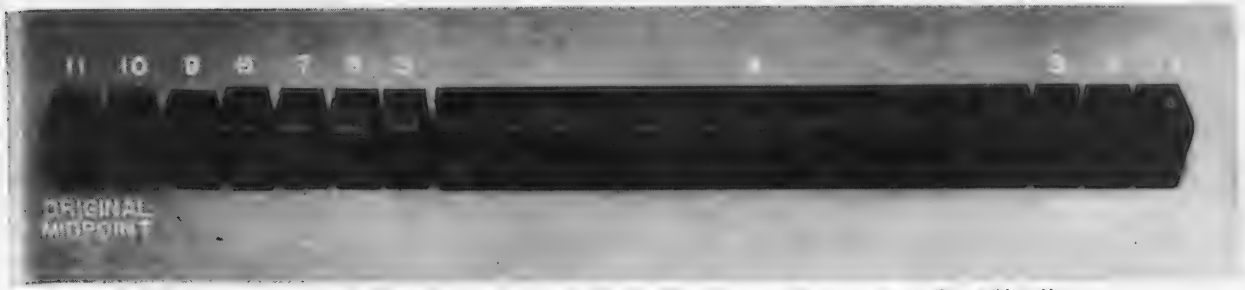

Figure 1.—Location of cross-sections relative to the original crossarm (pressure treated arm No. 4).

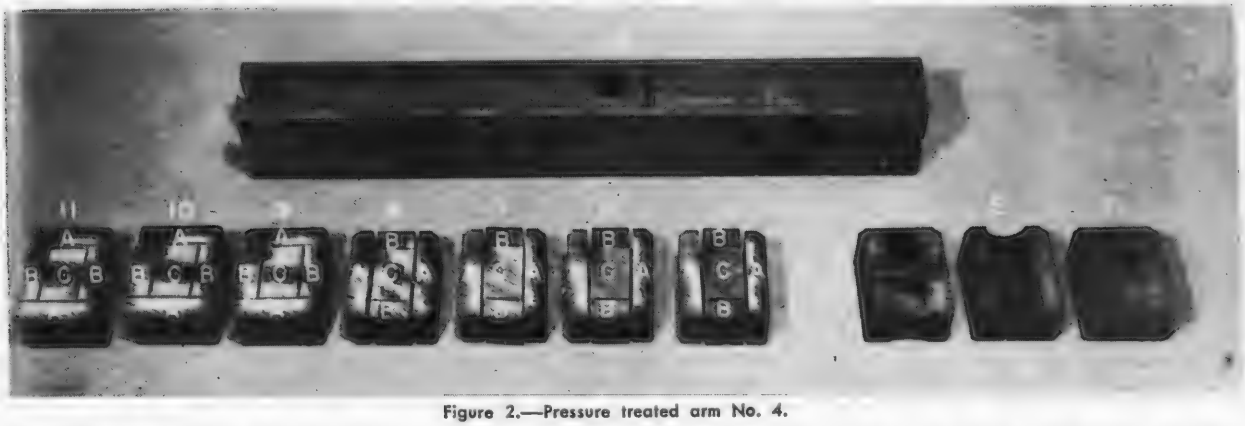

Figure 2.—Pressure treated arm No. 4.

in. x 4-1/4 in. Douglas fir crossarms taken from a total shipment of 2084 arms. These 2084 arms were also treated in two batches and the six arms selected were picked at random without regard to batch. The six arms were however restricted to arms having 100 per cent heartwood and had been incised on all four planed surfaces prior to treatment.

The treatment given these arms is also shown in Table I.

The solution used contained 5.2 per cent pentachlorophenol by weight and the petroleum solvent used had a specific gravity of 0.971 at 60/60 F. The arms were reported by the treating company to have an average retention of approximately 6 lb/cu. ft.

Sample Preparation

Each arm to be analyzed was cut in half at the center bolt hole. Six of these half arms for each type of treatment, pressure or non-pressure, were then further sectioned for analysis as shown in Fig. 1 and 2.

Starting from the original end of the arm the following cross-sections were cut: three 2-in. sections (No. 1, 2, and 3), a 28-in. section (No. 4), an 8-in. section, (shown in Fig. 1 as four 2-in. sections No. 5, 6, 7, and 8), and a 6-in. section (shown as three 2-in. sections, No. 9, 10, and 11). Before cutting into 2-in. sections, the 8-in. section was cut longitudinally into five pieces by sawing 3/4-in. thick slabs from the 4-1/4-in. faces and then 3/4-in. thick slabs from the 3-1/4-in. faces. These pieces were then regrouped and cut into the 2-in. lengths shown as 5, 6, 7, and 8 in Fig. 1 and 2.

The 8-in. section was cut longitudinally first and then into cross-sections to prevent oil and pentachlorophenol carry-over by the saw blade from the more heavily treated outer area to the center of the cross-sections. The 4-1/4 faces were cut before the 3-1/4 faces because the latter were susceptible to end penetration from the adjacent pinhole as well as radial penetration. These outside pieces in cross-sections 5 through 11 were cut primarily to show the extent of radial penetration.

The 6-in. section was cut in a similar manner except that the first cut in the 6-in. section was made on the 3-1/4-in. face, the 4-1/4-in. face of this section being influenced by the center bolt hole. The pieces are shown regrouped as No. 9, 10, and 11, in Fig. 1 and 2.

The sections cut from the crossarms were then ground to coarse sawdust in a Viking hammer mill to obtain samples of suitable form for analysis. The sections were ground individually or in groups as shown in Table II.

Analytical Methods and Results

The samples were analyzed for their pentachlorophenol content by the lime fusion method prescribed by the American Wood Preservers' Association[4]. The results of the anlysis of the various sections of the crossarms studied are recorded in Table II.

The average concentration of the treating solution in the crossarms was

[4] Proceedings, American Wood Preservers Assoc. 49, 70 (1953).

Table I.—TREATMENT DATA

Type of treatment	No. of arms treated	Step	Treatment		
			Pressure, psig	Temperature, F	Time, minutes
Pressure	1080	(1)	0	187-225	45
		(2)	73	200-187	20
		(3)	0	225-231	120
	1200	(1)	0	156-225	75
		(2)	74	158	20
		(3)	0	225-233	135
Non-pressure	1080	(1)	0	240	120
		(2)	0	140	170
	1004	(1)	0	226	120
		(2)	0	135	150

Table II.—SUMMARY OF PENTA RETENTIONS OF CROSSARM SECTIONS, LB./CU. FT.

Treatment	Crossarm No.	Section sampled*																						
		1	2	3	4	5A	5B	5C	6A	6B	6C	7A	7B	7C	8A	8B	8C	9A	9B	9C	10A	10B	10C	11A	11B	11C
Modified pressure (incised)	1	-----	0.373	-----	0.154	-----	-----	0.432	-----	-----	-----	-----	-----	-----	0.135	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0.135
	2	-----	0.324	-----	0.277	-----	-----	0.440	-----	-----	-----	-----	-----	-----	0.218	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0.180
	3	-----	0.432	-----	0.303	-----	-----	0.358	-----	-----	-----	-----	-----	-----	0.222	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0.156
	4	0.269	0.244	0.278	0.205	0.154	0.376	0.378	0.141	0.239	0.278	0.145	0.163	0.141	0.137	0.137	0.070	0.187	0.153	0.111	0.168	0.185	0.116	0.179	0.201	0.168
	5	-----	0.286	-----	0.157	-----	-----	0.530	-----	-----	-----	-----	-----	-----	0.138	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0.149
	6	-----	0.310	-----	0.213	-----	-----	0.539	-----	-----	-----	-----	-----	-----	0.253	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0.222
			1.969		1.309			2.677							1.103											1.010
	1,2,3,5,6	0.350	-----	0.369	-----	0.186	0.514	-----	0.192	0.328	0.246	0.176	0.267	0.123	-----	0.189	0.058	0.197	0.183	0.030	0.174	0.208	0.063	0.193	0.241	-----
	Average	0.337	0.328	0.354	0.218	0.182	0.491	0.446	0.184	0.313	0.251	0.171	0.250	0.126	0.184	0.180	0.060	0.195	0.178	0.044	0.173	0.204	0.072	0.191	0.234	0.168
Average on 6 lb/cu ft basis (6/4-52)		0.447	0.435	0.470	0.289	0.242	0.652	0.592	0.244	0.415	0.333	0.227	0.332	0.167	0.244	0.239	0.080	0.259	0.236	0.058	0.230	0.271	0.096	0.253	0.311	0.223
Non-pressure (incised)	1	-----	0.443	-----	0.190	-----	-----	0.366	-----	-----	-----	-----	-----	-----	0.185	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0.118
	2	-----	0.479	-----	0.236	-----	-----	0.202	-----	-----	-----	-----	-----	-----	0.238	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0.218
	3	-----	0.828	-----	0.619	-----	-----	0.671	-----	-----	-----	-----	-----	-----	0.624	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0.306
	4	0.396	0.385	0.359	0.157	0.274	0.429	0.169	0.258	0.302	0.058	0.248	0.231	0.061	0.322	0.185	0.058	0.266	0.262	0.045	0.269	0.266	0.052	0.221	0.217	0.058
	5	-----	0.377	-----	0.254	-----	-----	0.326	-----	-----	-----	-----	-----	-----	0.194	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0.138
	6	-----	0.759	-----	0.722	-----	-----	0.848	-----	-----	-----	-----	-----	-----	0.688	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0.315
			3.271		2.178			2.582							2.251											1.153
	1,2,3,5,6	0.572	-----	0.464	-----	0.447	0.653	-----	0.405	0.544	0.158	0.399	0.434	0.082	-----	0.392	0.058	0.423	0.399	0.048	0.439	0.399	0.090	0.376	0.389	-----
	Average	0.543	0.545	0.438	0.363	0.418	0.616	0.430	0.381	0.504	0.141	0.374	0.400	0.079	0.375	0.358	0.058	0.397	0.393	0.048	0.411	0.377	0.084	0.350	0.360	0.192
Average on 6 lb/cu ft basis (6/7-32)		0.445	0.447	0.359	0.298	0.343	0.505	0.353	0.312	0.413	0.116	0.307	0.328	0.065	0.308	0.294	0.048	0.326	0.322	0.039	0.337	0.309	0.069	0.287	0.295	0.157

*These section designations are shown in Figs. 1 and 2.

determined as follows: 1) The average quantity of pentachlorophenol found in the crossarms representing each treatment was calculated from the average concentration of pentachlorophenol found in each group of crossarm sections and from the average measured volume of the sections. 2) Knowing the amount of pentachlorophenol in the original treating oil, the amount of treating solution originally in the crossarms could then be calculated. The average concentration of treating solution in the pressure-treated arms was 4.52 lb/cu ft and the average concentration of treating solution in the non pressure-treated arms was 7.32 lb/cu ft. These retentions are not necessarily characteristic of the two methods o treatment, since a slight variation in treating temperatures or time would increase or decrease the total retention obtained. For a given total retention however, some comparisons of penta chlorophenol distribution can be made For convenience in making this comparison the average results reported in Table II for the sections analyzed were recalculated to give an estimate of what the retentions would have been in these same sections if the crossarms had received a 6 lb/cu ft average concentration of oil instead of the 4.52 and 7.32 lb/cu ft they were calculated to have contained.

Conclusions

Non-pressure-treated arms were found to have relatively lower pentachlorophenol retentions adjacent to the pin and bolt holes than pressure-treated arms. They had higher retentions in the incised surfaces and retentions similar to pressure-treated arms in the ends. In the least accessible portions of the arms, that is, the centers of cross-sections farthest from pin or bolt holes, the non-pressure-treated arm had lower retention than the pressure-treated arms. Nevertheless, preservative penetrated these areas in the non-pressure-treated arms and relatively good retentions were obtained. A reasonable comparison of the penetrations obtained can be made visually by comparing Fig. 2 and 4, and 3 and 5.

Perhaps the most significant difference found between the two types of treatments was the variation in pentachlorophenol retentions found between similar sections of the individual arms. The pentachlorophenol retentions found in similar sections of the non-pressure-treated arms, for example, varied twice as much as the retentions of similar sections in arms treated by pressure processes.

Figure 3.—Pressure treated arm No. 4 with sections opened.

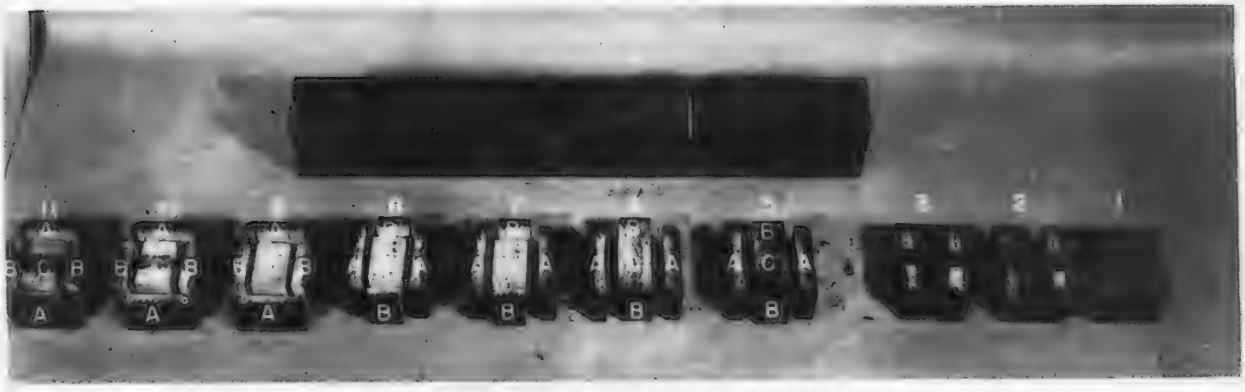

Figure 4.—Non-pressure arm No. 5.

Figure 5.—Non-pressure arm No. 5 with sections opened.

Swelling of Paint Films in Water, III[1]

Absorption and Volumetric Swelling of Bound and Free Films From Air of Different Relative Humidities

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This, the third paper in a series, shows that both free and bound films (coatings on glass) absorb moisture from damp air and swell, though the absorption is much less than it is when the films are soaked in water. The measurements in air are complicated by the fact that the films lose weight during the tests from escape of volatile decomposition products steadily formed by oxidation of the paint oils. At low relative humidities such losses overbalance any absorption of moisture.

THE TWO PREVIOUS PAPERS in this series (1, 2)[3] showed that films of house paints, when immersed in water, absorb much of the water and swell in volume. Although bound films (coatings on glass) absorb and swell somewhat less than free films, the imbibition by bound films is still large, particularly if the paint contains pigments that stimulate absorption. The purpose of the experiments reported in this paper was to learn whether bound and free films take up moisture from damp air and, if so, how the extent of the changes varies with the relative humidity of the air.

The experimental technique used to measure absorption, changes in volume, area, and thickness, and loss of soluble and volatile substances during the test period was described in the second paper (2). Five coating materials were selected from those previously tested in water, namely, unpigmented linseed oil and 4 single-pigment paints of 0.30 percent pigment volume made with magnesium silicate, basic carbonate white lead, zinc oxide, and anatase titanium dioxide, respectively. The white lead paint is one of relatively low absorption, the zinc oxide paint is very high in absorption, and the magnesium silicate and titanium dioxide paints are of intermediate absorption.

Bound films were spread on clean glass microscope slides of 1.5 by 3 inches in size. Free films were made from coatings spread on gummed paper. Linseed oil was applied by brushing in three successive coats a day apart. Paints were spread in one application by a doctor blade. The coatings were allowed to dry in a laboratory near a window with northern exposure that was kept closed. Free films were stripped from gummed paper when they had dried for 10 days. They were then cut to 1.5 by 2.5 inches in size and marked in waterproof drawing ink with datum lines for measurement of length and width with a traveling microscope. Each film was equipped with a suitable suspending hook made of copper wire and carefully cut to weight 0.0461 gram in air. The hook supplied a means of suspending the films freely in the air of the humidity rooms and also from the arm of a balance for weighing in air and in water.

Both free films and coatings on glass were dried in a desiccator over calcium chloride before they were weighed initially in air and in distilled water. They were then promptly moved to the humidity room in which they were to be tested. Coatings on glass were supported on shelves of open wire mesh through which air circulated freely. Free films were suspended to expose both faces to the air. Separate samples of each paint were provided for each humidity condition and for each period of exposure. One complete set of films was exposed for 3 days and another complete set for 7 days. In all humidity rooms the air was maintained at 80° F. Five rooms were available in which the relative humidity was held at 97, 90, 80, 65, and 30 percent, respectively. Additional sets of specimens were kept in desiccators over calcium chloride for 3 and for 7 days to provide exposure to nearly complete dryness. The specimens were 14 days' old on entering the 97 and 90 percent humidity rooms, 20 days' old on entering the 80 and 65 percent humidity rooms, and 24 days' old on entering the 30 percent humidity room or the desiccators.

For weighing the specimens in the humidity rooms at the conclusion of the test period a chainomatic balance and a traveling microscope were mounted on a suitable cart to be moved to the room in which measurements were to be made. Thus, the "swollen" weights and dimensions were determined without ambiguity from changes taking place during the time of measurement. Specimens from the desiccators were measured with the equipment standing in the Laboratory, but the results show that moisture changes at low relative humidities are negligible.

The data given in tables 1 and 2 for absorption during immersion in water for 3 days were taken from the previous paper (2). That paper should also be consulted for the methods of calculating results, except for an additional provision described in the fourth paragraph following.

Results

Results with bound films (coatings on glass) are given in table 1, those with free films exposed for 3 days in table 2, and those for free films exposed for 7 days in table 3.

Much less moisture was absorbed from damp air than from contact with water during immersion. Even in 97 percent relative humidity the absorption was never much more than a third, and often it was less than a fifth of the absorption from water. Nevertheless, there was measurable absorption at the higher humidities by all paints except white lead paint in free films and in the bound film of longer exposure. At 30 percent relative humidity no paint took up a measurable amount of moisture.

The absorptions recorded, however, are probably underestimated, particularly so at the intermediate and lower humidities, because there was a steady loss of volatile substances from all of the films throughout the periods of exposure. This loss, except for the more absorptive paints at the higher humidities, is comparable in magnitude to the moisture absorbed. Moreover, it is unlikely that the loss of volatile substances is reliably measured by the losses in weight during test recorded in the tables, for the volatile substances given off arise chiefly from disruptive oxidation of the oil vehicle and

[1] A contributed paper.
[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.
[3] Numbers in parentheses refer to references at end of text.

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Table 1.—DATA FOR BOUND FILMS (coatings on glass) OF LINSEED OIL AND OF FOUR PAINTS TESTED BY IMMERSION IN WATER FOR 3 DAYS AND BY EXPOSURE TO AIR OF DIFFERENT RELATIVE HUMIDITIES FOR 3 DAYS AND FOR 7 DAYS—ABSORPTION OF WATER OR OF MOISTURE, VOLUMETRIC SWELLING, SWELLING EFFICIENCY, CHANGES IN VOLUME ON REDRYING, AND LOSS IN WEIGHT DURING TEST

Paint or clear vehicle (density of nonvolatile while liquid)	Whether tested in water or in air of the relative humidity (R.H.) indicated	3-day test period: Density	Film thickness T_o	Absorption A/V_o	Swelling in volume ΔV_o	Swelling efficiency $\Delta V_s V_o/A$	Redried change in volume ΔV_r	Loss in weight during test S_2/V_o	7-day test period: Density	Film thickness T_o	Absorption A/V_o	Swelling in volume ΔV_o	Swelling efficiency $\Delta V_s V_o/A$	Redried change in volume ΔV_r	Loss in weight during test S_2/V_o
			Mils	Percent	Percent	Percent	Percent	Percent		Mil	Percent	Percent	Percent	Percent	Percent
Raw linseed oil (0.933)	Water	1.15	2.7	17.5	18.3	104	-3.7	4.6	(1)						
	Air, 97% R.H.	1.12	3.8	5.5	6.8	124	-3.2	2.4	1.12	3.0	5.9	5.9	100	-2.3	3.2
	Air, 90% R.H.	1.11	3.3	2.9	4.2	144	-3.1	2.0	1.12	3.5	2.9	2.9	100	-2.2	2.9
	Air, 80% R.H.	1.13	3.7	2.9	2.1	72	-.8	2.0	1.12	3.4	2.4	1.3	54	-.6	2.4
	Air, 65% R.H.	1.14	2.8	2.3	2.0	87	+.3	1.6	1.12	4.2	2.1	2.0	95	-.6	1.5
	Air, 30% R.H.	1.12	3.1	0	0		-1.3	1.7	1.11	4.4	0	0		-.9	1.5
	Air, dry	1.13	3.0	0	0		-.5	.9	1.12	3.3	0	0		-.6	1.3
Magnesium silicate p/nv 0.30 (1.515)	Water	1.70	3.3	40.7	41.9	103	-2.9	3.2	(1)						
	Air, 97% R.H.	1.64	4.6	9.5	10.5	110	-2.5	1.6	1.66	4.1	9.3	9.1	98	-1.7	2.5
	Air, 90% R.H.	1.66	3.8	3.0	4.1	137	-2.7	1.8	1.66	3.9	3.5	3.3	94	-1.7	2.3
	Air, 80% R.H.	1.68	4.1	2.2	1.4	64	-.3	1.6	1.69	3.9	2.4	1.0	42	-.1	2.2
	Air, 65% R.H.	1.69	3.8	1.4	.6	43	+.5	1.1	1.69	3.7	1.5	.3	20	+.7	1.3
	Air, 30% R.H.	1.68	3.8	0	0		-.7	.9	1.68	3.6	0	0		-.5	1.4
	Air, dry	1.68	3.9	0	0		-.7	.7	1.67	3.7	0	0		-.2	.8
Basic carbonate white lead, L, p/nv 0.30 (2.705)	Water	3.00	3.5	8.1	8.7	107	-2.0	3.0	(1)						
	Air, 97% R.H.	2.92	3.5	2.9	4.2	144	-2.8	2.3	2.92	3.4	0	0		-2.1	3.3
	Air, 90% R.H.	2.92	3.3	0	0		-2.8	1.9	2.93	3.3	0	0		-1.5	2.6
	Air, 80% R.H.	2.98	3.3	0	0		+.2	2.1	2.97	3.3	0	0		-.3	2.4
	Air, 65% R.H.	2.98	3.2	0	0		+.6	1.1	2.97	3.3	0	0		+.5	1.2
	Air, 30% R.H.	2.94	3.2	0	0		-.8	.9	2.94	3.5	0	0		-.6	1.1
	Air, dry	2.93	3.6	0	0		-.7	.3	2.95	3.4	0	0		+.2	.6
Zinc oxide, Z, p/nv 0.30 (2.345)	Water	2.51	2.8	62.7	62.0	99	+1.2	2.3	(1)						
	Air, 97% R.H.	2.46	3.3	16.0	16.9	106	-1.5	.4	2.46	3.4	20.0	19.2	96	-.04	.6
	Air, 90% R.H.	2.46	3.0	2.5	3.8	152	-1.5	.2	2.46	3.3	2.4	2.0	83	+.4	.1
	Air, 80% R.H.	2.49	3.4	2.2	.9	41	+.8	.7	2.48	3.3	2.0	.2	10	+1.0	.5
	Air, 65% R.H.	2.50	3.3	1.6	.7	44	+1.3	.3	2.51	3.2	1.5	.5	33	+1.7	.3
	Air, 30% R.H.	2.49	3.4	0	0		-.4	.9	2.47	3.9	0	0		-.2	.9
	Air, dry	2.48	3.5	0	0		-.5	.5	2.47	3.3	0	0		-.3	.8
Titanium dioxide, anatase type, T_{420}, p/nv 0.30 (1.820)	Water	2.02	2.6	23.5	24.9	106	-3.0	3.4	(1)						
	Air, 97% R.H.	1.95	4.5	4.0	5.4	135	-2.2	1.0	1.93	3.8	5.0	5.2	104	-1.7	1.9
	Air, 90% R.H.	1.96	3.9	1.9	3.1	163	-2.2	1.1	1.95	4.2	2.1	2.2	105	-1.7	1.6
	Air, 80% R.H.	1.97	4.5	1.7	1.0	59	-.3	1.1	1.98	4.2	2.0	.9	45	-.9	1.7
	Air, 65% R.H.	1.98	4.3	1.2	1.1	92	+.2	.8	1.98	4.3	1.2	.1	8	+.6	.7
	Air, 30% R.H.	1.98	4.0	0	0		-.6	.9	1.98	4.0	0	0		-.9	1.3
	Air, dry	1.96	4.0	0	0		-.8	.7	1.98	4.2	0	0		-.6	.6

[1] Not tested by immersion in water for 7 days.

include the weight of part, though probably not all, of the oxygen taken from the air. To measure the hygroscopicity of paint films precisely, especially when the absorption is small, it would be necessary to exclude oxygen entirely and to expose the films during the test period to an inert gas humidified to the desired extent. For present purposes, however, it is considered sufficient to establish merely the order of magnitude of the effects.

It is probable then that the films absorbed somewhat more moisture than appears in the tables, especially at the lower relative humidities. Where the absorption and swelling are recorded as zero at or above 30 percent relative humidity, there may in fact have been a slight absorption, not greater than the loss in weight during the test period. It should be noted that the absorption and swelling were recorded as zero whenever the measurements after 3 or 7 days' exposure failed to exceed the initial measurements. Usually if no gain in weight, volume, or area was registered during the period of exposure, there was a slight loss which is included in the records of loss in weight and the changes in volume and area after redrying.

Comparison of the 7-day with the 3-day periods of test shows that significant absorption of moisture was nearly always complete within 3 days, but that loss of volatile substances usually continued up to the seventh day. (In fact, films of paint L, p/nv 0.30, and paint TZ_{20}, p/nv 0.30, kept on a desk top in a laboratory in only moderate illumination about 10 feet from a window with northern exposure, were still losing weight progressively after a year and a half.) Better estimates of the absorption of moisture and swelling with less distortion by loss of volatile substances were obtained in the 3-day than in the 7-day test period. Perhaps a 1-day test period would have been still better and might have indicated a small positive absorption at some of the higher humidities in which zero absorption was recorded after 3 days.

Bound Films: The absorption of moisture in 3 days (table 1) exceeded the loss of volatile products at 65 percent and higher relative humidity for raw linseed oil and all paints except white lead paint. For white lead paint there was measurable absorption only at 97 percent relative humidity. White lead paint was also lowest in absorption when soaked in water. Above 65 percent, the absorption increased at each higher step in relative humidity, with the largest increase occurring between 90 and 97 percent, although the increase was by no means so large as that on going from 97 percent relative humidity to soaking in water. None of the paints showed measurable absorption in 30 percent relative humidity, and of course there was none in dry air.

White lead paint absorbed less than linseed oil both in 97 percent relative humidity and in water. Titanium dioxide paint absorbed a little more water but a little less moisture in 97 percent relative humidity than linseed oil did. Magnesium silicate paint had significantly greater absorption than linseed oil both in water and in 97 percent relative humidity, and zinc oxide paint

Table 2.—DATA FOR FREE FILMS OF LINSEED OIL AND OF FOUR PAINTS TESTED BY IMMERSION IN WATER AND BY EXPOSURE TO AIR OF DIFFERENT RELATIVE HUMIDITIES FOR 3 DAYS—ABSORPTION OF WATER OR MOISTURE, SWELLING IN VOLUME, AREA, AND THICKNESS, SWELLING EFFICIENCY, CHANGES IN VOLUME, AREA, AND THICKNESS ON REDRYING, AND LOSS IN WEIGHT DURING TEST

Paint or clear vehicle (density of nonvolatile while liquid)	Whether tested in water or in air of the relative humidity (R.H.) indicated (test period 3 days)	Before testing: Density	Before testing: Film thickness T_o	Absorption A/V_o	Swelling: In volume ΔV_s	Swelling: In area ΔQ_s	Swelling: In thickness ΔT_s	Swelling efficiency $\Delta V_s V_o/A$	Redried change: In volume ΔV_r	Redried change: In area ΔQ_r	Redried change: In thickness ΔT_r	Loss in weight during test S_2/V_o
			Mils	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Raw linseed oil (0.933)	Water	1.11	3.1	21.8	22.0	9.8	10.8	101	-6.0	-4.9	-1.3	5.8
	Air, 97% R.H.	1.12	2.6	5.6	7.9	3.5	4.2	141	-3.0	.....	.....	3.3
	Air, 90% R.H.	1.11	3.1	3.1	4.0	1.9	1.9	129	-2.9	-.7	-1.9	2.5
	Air, 80% R.H.	1.13	3.4	2.3	2.5	2.5	0	109	-2.1	-2.7	+.6	2.7
	Air, 65% R.H.	1.12	3.3	4.7	4.8	.....	1.2	102	-3.8	.....	.....	4.3
	Air, 30% R.H.	1.12	3.0	0	0	0	0	.....	-2.3	-1.8	-.7	1.8
	Air, dry	1.13	3.3	0	0	0	0	.....	-1.3	-.9	-.6	1.1
Magnesium silicate p/nv 0.30 (1.515)	Water	1.68	2.9	56.2	56.1	15.9	31.5	100	-3.8	+2.2	-6.1	4.5
	Air, 97% R.H.	1.63	4.5	9.4	10.1	3.8	6.2	108	-2.4	-.3	-2.2	2.3
	Air, 90% R.H.	1.64	4.3	2.8	3.2	1.3	2.1	114	-2.0	-.3	-2.3	2.1
	Air, 80% R.H.	1.64	4.6	1.9	2.1	1.1	1.1	111	-2.0	-1.1	-1.1	2.3
	Air, 65% R.H.	1.63	4.1	0	0	.9	0	.....	-2.0	-.6	-1.5	2.1
	Air, 30% R.H.	1.65	4.5	0	0	0	0	.....	-1.7	-.8	-1.1	1.4
	Air, dry	1.65	4.2	0	0	0	0	.....	-1.2	-.5	-1.0	1.4
Basic carbonate, white lead, L, p/nv 0.30 (2.705)	Water	2.98	2.8	10.0	9.2	4.7	1.1	92	-3.9	-.2	-3.6	6.1
	Air, 97% R.H.	2.90	3.7	0	0	0	0	.....	-1.8	-.8	-1.1	2.2
	Air, 90% R.H.	2.92	3.7	0	0	0	0	.....	-1.5	-.9	-.5	1.8
	Air, 80% R.H.	2.92	3.4	0	0	0	0	.....	-2.0	-.8	-1.2	2.3
	Air, 65% R.H.	2.92	3.6	0	0	0	0	.....	-1.1	-.7	-.6	1.4
	Air, 30% R.H.	2.94	3.8	0	0	0	0	.....	-.4	-.4	0	.6
	Air, dry	2.93	3.6	0	0	0	0	.....	-.7	-.5	-.3	.9
Zinc oxide, Z, p/nv 0.30 (2.345)	Water	2.46	2.5	96.7	96.5	65.9	16.8	100	-3.5	+24.6	-22.4	6.3
	Air, 97% R.H.	2.45	3.4	15.8	19.7	9.2	9.4	125	-.5	+1.1	-1.8	.6
	Air, 90% R.H.	2.45	3.4	1.5	2.6	.9	1.8	173	-.7	0	-.7	.5
	Air, 80% R.H.	2.46	3.3	1.1	1.8	1.0	.9	164	-1.5	+.1	-1.3	1.7
	Air, 65% R.H.	2.46	3.3	1.4	1.4	1.1	.3	100	-.7	-.4	-.5	1.2
	Air, 30% R.H.	2.47	3.3	0	0	0	0	.....	-.7	-.3	-.6	.5
	Air, dry	2.46	3.4	0	0	0	0	.....	-.6	-.1	-.5	.6
Titanium dioxide, anatase type, T_{420}, p/nv 0.30 (1.820)	Water	2.02	2.7	25.6	25.3	13.5	6.9	99	-4.1	+1.0	-4.7	5.2
	Air, 97% R.H.	1.97	3.8	3.3	4.1	2.3	1.9	125	-1.8	-.8	-1.1	1.5
	Air, 90% R.H.	1.97	3.6	1.8	3.0	1.3	1.7	167	-1.9	-1.3	-.6	1.4
	Air, 80% R.H.	1.98	3.7	0	0	0	0	.....	-2.5	-.8	-1.6	2.4
	Air, 65% R.H.	1.98	3.9	0	0	0	0	.....	-1.9	-1.5	-.3	1.7
	Air, 30% R.H.	1.99	3.8	0	0	0	0	.....	-1.8	-.5	-1.3	1.4
	Air, dry	1.98	3.9	0	0	0	0	.....	-1.9	-.6	-1.3	1.4

had the highest absorptions under both conditions. Zinc oxide paint took up almost as much moisture from 97 percent relative humidity as linseed oil gained when soaked in water; but at 90 percent and lower relative humidities the absorption by zinc oxide paint was not significantly greater than that of the other paints.

At 90 and 97 percent relative humidities the volumetric swelling of all paints exceeded their absorption of moisture. The swelling efficiency ranged from 106 to 163 percent. To be sure, the largest efficiencies occurred where absorption and swelling were not very great and experimental error was therefore relatively large, but the tendency for the efficiency to exceed 100 percent was consistent. When the films were soaked in water, the swelling efficiency likewise usually exceeded 100 percent, but by a margin small enough to be attributed (2) to experimental error due to slight loss of water during the time required to blot up the water clinging to the surfaces of the wet films and weigh them. There were no such losses in 90 and 97 percent relative humidities because the weighings were made while the films were still in the humidity rooms. After the 7-day test period the swelling efficiencies dropped nearly to or even slightly below 100 percent for bound films, but for the free films in table 3 the efficiencies remained above 100 percent. For bound films at 80 percent relative humidity or less, the swelling efficiency was always less, usually far less, than 100 percent; but for free films (tables 2 and 3) the efficiencies exceeded 100 percent, sometimes by a wide margin, even at relative humidity as low as 65 percent.

More study is needed to explain the large swelling efficiencies. Perhaps the marked shrinkage in volume that occurs during the conversion of the liquid coating to a hardened film, which is disclosed by a large increase in density, puts the hardened film in compression. At this stage the linoxyn vehicle consists of a cross-linked network of a "solid phase" that encloses and possibly compresses a large proportion of "liquid phase" (4). When the film is then moved to a moist atmosphere, the moisture absorbed plasticizes the rigid solid phase sufficiently for it to yield under the pressure of the liquid phase. Thus, there may be a springback of volume added to the volume of the absorbed water itself. Plasticization by absorbed moisture markedly affects the mechanical properties of paint films (3).

When redried over calcium chloride after testing in damp air, most bound films shrank to a volume smaller than that when the test began. Such shrinkage was inversely related to the extent of swelling; that is, films tested in 9 percent relative humidity swelled more and then shrank more afterward than films tested in 90 percent relative humidity, and those tested in 90 percent swelled and shrank more than those tested in 80 percent relative humidity. The shrinkage below the initial volume

Table 3.—DATA FOR FREE FILMS OF LINSEED OIL AND OF FOUR PAINTS TESTED BY EXPOSURE TO AIR OF DIFFERENT RELATIVE HUMIDITIES FOR 7 DAYS—ABSORPTION OF MOISTURE, SWELLING IN VOLUME, AREA, AND THICKNESS, SWELLING EFFICIENCY, CHANGES IN VOLUME, AREA, AND THICKNESS ON REDRYING, AND LOSS IN WEIGHT DURING TEST

Paint or clear vehicle (density of nonvolatile while liquid)	Whether tested in water or in air of the relative humidity (R. H.) indicated (test period 7 days)	Before testing: Density	Film thickness T_o	Absorption A/V_o	Swelling: In volume ΔV_s	Swelling: In area ΔQ_s	Swelling: In thickness ΔT_s	Swelling efficiency $\Delta V_s V_o/A$	Redried change: In volume ΔV_r	Redried change: In area ΔQ_r	Redried change: In thickness ΔT_r	Loss in weight during test S_2/V_o
			Mils	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Raw linseed oil (0.933)	Air, 97% R.H.	1.12	2.7	0	0	.....	0	.....	-4.4	-2.6	-4.4	5.9
	Air, 90% R.H.	1.12	2.7	0	0	0.9	2.6	.....	-2.8	.....	-3.0	4.2
	Air, 80% R.H.	1.12	3.0	0	0	0	0	.....	-3.4	-3.0	-3.0	3.6
	Air, 65% R.H.	1.13	3.0	2.8	3.4	0	.7	121	-2.6	-1.4	-2.7	2.4
	Air, 30% R.H.	1.11	2.6	0	0	0	.....	.....	-3.6	-2.3	-3.4	2.8
	Air, dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Magnesium silicate p/nv 0.30 (1.515)	Air, 97% R.H.	1.63	4.3	6.9	7.4	2.5	4.4	107	-3.1	-.6	-3.0	2.8
	Air, 90% R.H.	1.62	4.1	3.2	3.8	1.1	1.0	119	-2.8	-.4	-3.0	3.1
	Air, 80% R.H.	1.64	4.6	0	0	0	0	.....	-2.7	-1.1	-2.4	2.9
	Air, 65% R.H.	1.65	4.3	0	0	0	0	.....	-1.9	-1.0	-1.6	1.7
	Air, 30% R.H.	1.65	4.4	0	0	0	0	.....	-2.5	-.8	-2.5	1.8
	Air, dry	1.65	4.5	0	0	0	0	.....	-1.6	-.5	-1.6	1.3
Basic carbonate, white lead, L, p/nv 0.30 (2.705)	Air, 97% R.H.	2.92	3.7	0	0	0	0	.....	-.2	-.6	-.3	2.9
	Air, 90% R.H.	2.91	3.6	0	0	0	0	.....	-2.3	-.6	-2.5	2.3
	Air, 80% R.H.	2.92	3.6	0	0	0	0	.....	-1.9	-1.0	-1.7	2.0
	Air, 65% R.H.	2.92	3.7	0	0	0	0	.....	-1.8	-.5	-1.9	1.7
	Air, 30% R.H.	2.92	3.6	0	0	0	0	.....	-2.0	-.5	-1.7	1.4
	Air, dry	2.92	3.9	0	0	0	0	.....	-1.8	-.5	-1.8	1.0
Zinc oxide, Z, p/nv 0.30 (2.345)	Air, 97% R.H.	2.44	3.5	13.4	19.6	6.2	18.3	146	-1.5	+3.5	-1.8	1.2
	Air, 90% R.H.	2.46	3.3	1.4	1.8	.5	1.2	129	-.6	-.4	-.3	.7
	Air, 80% R.H.	2.46	3.7	1.0	1.6	.6	.3	160	-1.2	-.6	-1.3	1.3
	Air, 65% R.H.	2.45	3.5	1.4	1.5	.2	.3	107	-1.1	-.6	-1.1	1.0
	Air, 30% R.H.	2.43	3.3	0	0	0	0	.....	-2.8	-.4	-3.0	2.5
	Air, dry	2.47	3.6	0	0	0	0	.....	-1.1	-.3	-.8	1.0
Titanium dioxide, anatase type, T_{420}, p/nv 0.30 (1.820)	Air, 97% R.H.	1.97	3.6	2.9	7.3	1.0	4.5	251	-3.2	-.4	-3.1	2.7
	Air, 90% R.H.	1.96	3.9	2.0	2.5	0	0	125	-2.4	-1.7	-2.5	2.1
	Air, 80% R.H.	1.98	3.6	0	0	0	0	.....	-2.7	-1.7	-2.8	2.8
	Air, 65% R.H.	1.98	3.6	0	0	0	0	.....	-1.6	-1.4	-1.4	1.6
	Air, 30% R.H.	2.00	3.6	0	0	0	0	.....	-2.5	-1.3	-2.2	1.7
	Air, dry	1.99	3.6	0	0	0	0	.....	-2.5	-.7	-2.5	2.1

was due partly, perhaps entirely, to loss of volatile substances during testing and redrying. But all bound films tested for 3 days in 65 percent relative humidity and the films of white lead paint and of zinc oxide paint tested for 3 days in 80 percent relative humidity remained slightly swollen after redrying over calcium chloride. Perhaps the degree of plasticization at these moderate relative humidities was insufficient to permit full shrinkage on redrying when all change in volume was confined to one dimension, thickness. The corresponding free films (tables 2 and 3), which could change in 3 dimensions, did shrink on redrying to less than the volume before testing. All films tested in 30 percent relative humidity or kept continuously in dry air, none of which experienced any swelling, came to a final volume smaller than their initial volume because of their loss of volatile substances.

Losses in weight during testing and redrying were greater when tests were made in 80 percent or higher relative humidity than when the tests were made in lower humidity. Apparently disruptive oxidation with formation of volatile substances goes on more rapidly in moist than in dry air. When films were soaked in water, however, the losses in weight were significantly greater than any of the losses in air. Water evidently extracts substances of low volatility that are probably present in the films before immersion in the water and that can be recovered by evaporation of the soaking water and drying the residue at 105° C.

Free Films: Although all of the free films absorbed more water than bound films when soaked in water, the absorption of moisture from damp air was not much greater, and usually was somewhat less, than that of corresponding bound films. Failure to find larger absorption by free than by bound films in air may be due in part to the relatively small absorption from air, which makes the difference between free and bound films still smaller. But in large part, the failure may be attributed to larger loss of volatile substances by the free films, both faces of which were exposed to oxidation, whereas only one face of the bound films was similarly exposed.

Absorption by free films paralleled that by bound films in that, except for anomalies with linseed oil and zinc oxide paint in 65 percent relative humidity, it was greater in 97 than in 90 percent and greater in 90 than in 80 percent relative humidity, and was less than the loss of volatile substances in 30 percent relative humidity and in dry air. Further, white lead paint absorbed less water than any other; in fact, none at all from air. Titanium dioxide paint absorbed less from air but a little more from water than linseed oil did; and magnesium silicate paint and zinc oxide paint absorbed more than linseed oil did, with the zinc oxide paint absorbing most of all.

With free films the volumetric swelling exceeded the absorption of moisture not only at 90 and 97 percent relative humidity but at 65 and 80 percent, provided that there was measurable absorption. If the excess swelling above the volume of moisture absorbed is due to springback from release of compression acquired during the original hardening of the coatings, it is perhaps not surprising for it to be more marked for free than for bound films.

Part of the volumetric swelling of free films expressed itself in swelling

in area and the balance in swelling in thickness. Although a real swelling usually increased with any marked increase in volumetric swelling, there were no fixed relations between them even for one kind of paint in different conditions of humidity.

On redrying after testing, all free films shrank to less than the volume before test. Usually they shrank also in area and thickness to less than the initial dimensions before test. However, zinc oxide paint in water and in 97 percent relative humidity and in 80 percent relative humidity for the 3-day period remained greater in area after redrying than it was initially, as did also the titanium dioxide paint and the magnesium silicate paint when soaked in water and redried.

Conclusions

Both free and bound films of linseed oil and of oil paints pigmented with magnesium silicate, white lead, zinc oxide, and titanium dioxide, respectively, absorbed moisture and swelled measurably when hung in damp air for 3 days, but the absorption and swelling were much less than when the films were soaked in distilled water. From damp air, the higher the relative humidity, the greater were the absorption and swelling; but at 30 percent relative humidity or lower, and at even higher relative humidity for the least absorptive paints, any absorption that may have occurred was overbalanced by loss in weight from evolution of volatile oxidation products. Pure white lead paint was less absorptive than any of the others. Titanium dioxide paint absorbed a little less from air but a little more from water than linseed oil did. Magnesium silicate paint and zinc oxide paint absorbed much more than linseed oil did, with zinc oxide paint absorbing most. Volumetric swelling often exceeded the volume of moisture absorbed. This may indicate a springback in volume from release of compression in a "liquid phase" of linoxyn acquired during the original hardening of the paint, brought about when the rigid "solid phase" is plasticized by absorbed moisture. Although free films absorbed and swelled more than bound films when soaked in water, when hung in damp air the free films absorbed little more, and usually less, than bound films. The free films with 2 faces exposed to the air lost more volatile substances than the bound films, only 1 face of which was exposed to air. When redried after testing, free films always shrank to less than their volume before test. Bound films shrank to less than the initial volume after test at high relative humidity, and also at low relative humidity where loss of volatile predominated over absorption; but after testing at intermediate relative humidities, bound films failed to shrink back as far as their initial volume. This may be further evidence of a rigid "solid phase" of linoxyn preventing free movement when insufficiently plasticized by absorbed moisture.

References

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Coatings That Prevent End Checks[1]

As wood dries, the surface fibers give up their moisture first and tend to shrink but are restrained from so doing by the interior fibers, which have not begun to shrink; thus drying stresses develop that tend to cause checks. The tendency to check is more pronounced on the end-grain than it is on the side-grain surfaces. A moisture-resistant end coating is often used to protect such surfaces from checking during air seasoning or kiln drying.

To be satisfactory for large-scale use, an end coating should have the following qualities:

1. Adequate resistance to water movement under all conditions of temperature and humidity to which it may be subjected during the drying of the wood.
2. Ease of application under a wide range of temperatures.
3. Sufficient toughness and adhesiveness to withstand rough handling and to prevent blistering and cracking during kiln drying.
4. Freedom from abrasive substances that may be injurious to saws or cutters during machining of the wood.
5. Low cost to cover a given area.

End coatings may be divided into two classes: those that are liquid at ordinary temperatures and can be applied without being heated, and those that are solid at ordinary temperatures and must be applied hot. Cold coatings can be applied readily to logs and lumber as well as to kiln samples and dimension stock. Hot coatings are well suited for use on small stock that can be easily handled, but they are not readily applied to logs and lumber.

Ordinary paints and varnishes are too thin for end coatings unless several coats are applied. A number of special end coatings of the cold-coating class are available from various manufacturers and dry kiln companies. Many of these are heavily filled varnishes, but there are other types such as heavy resin solutions, asphalt semimastic, and emulsified asphalt, wax, or synthetic resin. The properties of emulsified preparations vary widely, depending upon the amount of water and type of emulsion. They are not satisfactory when subjected to rain or freezing soon after application.

The effectiveness of commercial end coatings can be tested by comparing them with either of the two end coatings originally developed by the Forest Products Laboratory, an aluminized varnish and filled, hardened gloss oil. Both have certain disadvantages for commercial use, but, when properly made, have a moderately high degree of water resistance and will stand up under a variety of kiln conditions. Filled, hardened gloss oil requires special preparation by a varnish manufacturer. Information on suppliers or the formula for preparation will be supplied by the Forest Products Laboratory upon request.

Cold coatings are usually applied by brush, although they can be sprayed. They also can be applied to small items by holding the ends against a roller that is rotated while partly submerged in the coating. Cold coatings should be allowed to dry a few hours before being subjected to kiln temperatures.

Hot coating materials include pitch, asphalt, and paraffin. They are low in cost and high in water resistance when applied in a single coat. They maintain a high degree of water resistance even after prolonged heating if the drying temperatures are kept about 30° F. or more below the softening point of the coating. Standard softening points are determined by the ring-and-ball method (A.S.T.M. Designation: E-28–51T).

Hot coatings can be prepared that will withstand any normal kiln temperature, but those with higher softening points tend to be less adhesive, more brittle, and more difficult to apply than those with lower softening points. A coating with the lowest softening point that will safely withstand the temperatures encountered during the drying should be used. Certain combinations of hot-coating materials can be mixed to obtain desired softening-point characteristics and improved adhesiveness and toughness.

Hot coatings can be easily applied to material of short length that can be manipulated by hand. The temperature at which hot coatings should be applied varies with the type used; pitch and asphalt coatings are applied at approximately 400° F. and paraffin at approximately 150° F. The coatings can be applied by dipping the ends of the stock into the molten coating to a depth of ½ inch, but better results are obtained by firmly holding the ends against a power-driven roller that is rotated while partly submerged in the heated coating. If the coatings are applied uniformly, a thickness of $\frac{1}{32}$ to $\frac{1}{16}$ inch is sufficient.

[1] Technical Note No. 186, Forest Products Laboratory, U.S.D.A. Forest Service, Madison 5, Wis. Rev. July 1953.

Equipment for Conditioning and Testing Wood in Small Plants[1]

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Discussion of tools needed to implement a quality control program and product development investigation. Principles given for construction and operation of a conditioning cabinet of relatively simple and economical design.

THE STORY OF THE LOSS of the unique position wood has held in the past is all too familiar to any man engaged in the manufacture of wood and wood based products. Today wood is a material competing to retain all its markets, even those for which its inherent properties make it most suitable and economical. As a competitive material each branch of the industry and each plant must fight to prove its technical and economic advantage. In general, the newer materials such as steel, aluminum and plastic have based their expanded use upon a sound foundation of basic research which has shown the exact technical properties of the particular material. This knowledge has then been used to guide a program for the quality control and use of the product.

Since research activities, on the whole, are outside the sphere which can normally be economical for small manufacturing plants, this discussion will be confined to those tools needed to implement a control program and product development investigations. Past experience has shown that application of these management techniques will force the product to maintain a standard of dependability and uniformity which will enable wood to compete with man-made materials.

Wood is a naturally formed product which is variable in all its properties. Therefore our problems when using it become a complex matter of the understanding of peculiarities in its behavior. No permanent solution of any problem in quality control or product development becomes feasible then until a given situation can be evaluated in terms of fundamentals. It is therefore apparent, that the first essential for an adequate program in any size of plant is the presence of at least one man who has a thorough understanding of wood and the technical processes employed in its handling. Only when such a man is on hand does the possession of testing equipment of one kind or another have any meaning. In most small to medium sized plants one good man can keep a program in operation even when large amounts of routine check material must be handled. In this latter case he can evaluate information obtained by non-technical assistants. For those plants too small to afford a good man, an obvious solution is the employment of a consultant.

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Testing Equipment

A consideration of required laboratory equipment indicates that a division can be made into primary and specialized items. The primary equipment applies to all types of industries and is of use for the indispensable examination of raw material and also for the later checking on semi-finished and complete products. A further division of the basic equipment can be made under several headings according to its employment.

The first classification is those tools needed for determination and/or control of moisture content and specific gravity. These are listed and discussed below.

1. **Metric Balance:** A wide variety of balance types are available from suppliers of scientific equipment. The choice depends on maximum capacity needed and accuracy, with the cost largely dependent on the latter factor. Standard measurements call for an accuracy of $\pm$ 0.2% when making precise moisture determinations. This usually limits the capacity in practice. If a single balance is to be purchased it is best to sacrifice the possibility of accuracy for specimens below 50 grams and to buy a triple-beam or trip balance with a normal capacity of 500 to 1000 grams and a sensitivity of 0.1 gram. These units cost less than $25.00 and can readily be supplemented by additional balances of greater sensitivity when required. An example of the more precise type is the small torsion balance with maximum capacity of 120 grams and sensitivity of 0.002 grams. Such a balance can give the required accuracy on samples whose weight is as low as two grams.

2. **Drying Oven:** Requirements for drying samples when determining moisture content call for controlling heating at 103 $\pm$ 2° Centigrade. For the usual small plant, an oven of one cubic foot capacity with thermostatically controlled heating elements will handle the work. Ovens of this sort are available from several scientific supply houses at about $150. Where faster drying is needed or larger volumes of material are to be handled, a forced draft oven might be more practical.

3. **Immersion Tanks and Coating Equipment:** When measuring the volume of samples by the balance displacement method, a light sheet metal tank 3x4x8 inches is necessary. This is standard but may be replaced by other systems such as overflow apparatus or a large, graduated cylinder. A necessary adjunct, to the water immersion is the surface coating of the specimen with paraffin. A heated bath can be used for this or a saturated solution of paraffin in carbon tetrachloride.

4. **Electric Moisture Meter:** The equipment so far discussed in this section is capable of giving a precise measure of the moisture content of a piece of wood and can be used for fairly large quantities of small samples. A need exists, however, in the usual manufacturing plant for a means to measure rapidly the moisture content without damaging the material. Such apparatus is available from several reputable makers any of whom will furnish useful meters. Experience has shown that when reliance must be placed on a single instrument, the resistance type will give less trouble than those built on the capacitance principle. In an, case, when drying and weighing equipment is available it is a simple matter to run check and calibration samples so that the accuracy may be known at any time.

5. **Sling Psychrometer:** The addition of this useful and inexpensive instrument to the basic list makes it possible to obtain the relative humidity of the air, vapor pressure and dew point. Knowledge of the moisture conditions at various places inside and outside of

the plant is often a key to difficulties in given situations.

A second type of equipment which is essential for reliable testing of wood and wood products is the equipment for conditioning wood prior to test. In the ideal case this consists of an entire air-conditioned room in which standard uniform conditions are maintained throughout the year. The testing and conditioning of the wood can then be carried out in the same room. Unfortunately, such air-conditioning facilities are expensive, requiring the skill of an air-conditioning specialist to design and install. Wood can, however, be conditioned to uniform and standard moisture content without the necessity of such elaborate and expensive equipment. This is possible by the use of a conditioning chamber or room in which the wood is brought to a desired moisture content prior to testing. This kind of equipment can be constructed at a wood-working plant with a minimum of cost by plant personnel. The principles of operation and construction of such wood-conditioning equipment are given in Part II of this paper.

A third major classification of the basic tools required may be made by grouping those which are used for dimensional measurements.

1. **Scales and Rules:** Several items in this class should be available. The most important is a twelve inch steel machinists rule with engine divided scales. Another useful item is a six foot flexible steel tape in a pocket case or a six foot folding rule.

Some equipment for weighing and measuring samples. A torsion balance and weights are shown, as well as a twelve-inch scale, a micrometer and a six-inch vernier caliper (photo by Wilfred A. Cote, Jr.).

2. **Calipers and Micrometers:** A good pair of vernier calipers of six inch capacity, reading to hundredths of an inch should be available. In addition, it is desirable to have a metric caliper. For more precise work these units can be supplemented with machinists micrometers reading to thousandths of an inch and dial indicators with their various styles of mountings to suit the requirements of the work.

3. **Slope of Grain Indicator:** A swivel-arm scribe with a replaceable phonograph needle point is an almost indispensable tool for examining timber. Descriptions of such an instrument and other apparatus for measuring slope of grain can be found in the Forest Products Laboratory Report No. 1585, dated 1943. This publication can be obtained free of cost.

A small conditioning cabinet constructed from ¾-inch plywood, showing observation window and two access doors. In the foreground is a representative electric moisture meter of the radio-frequency power-loss type (photo by Wilfred A. Cote, Jr.).

Another grouping of equipment in the primary list is items required for wood structural examination.

1. **Pocket Knife:** The only requirement is that the knife be a reasonable size and have blades of high quality steel which can take a good edge. Single edge razor blades are, in some cases, a handy addition.

2. **Hand Lens:** A folding, pocket type hand lens with a magnifying power of 10X to 20X is most suitable and will show sufficient detail for ordinary work.

3. **Electric Hot Plate:** A 110–115 volt, 500 watt electric hot plate with a built in temperature control is needed for a number of jobs such as softening samples prior to examination, and making delamination tests.

The last classification of items needed for the primary laboratory equipment in small plants is a limited group of reference sources.

1. *Wood Handbook,* Forest Products Laboratory, U.S.D.A., Washington, D.C., 1940.

   This publication is a mine of information for any person working with wood. It is currently under revision and some parts can be obtained separately from the laboratory at Madison.
2. Wangaard, F. F., *The Mechanical Properties of Wood.* John Wiley and Sons, 1950.

   A valuable source of information because of the assemblage and discussion of the various factors that affect strength in wood.
3. Brown, H. P., A. J. Panshin and C. C. Forsaith, *Textbook of Wood Technology,* Vol. I, McGraw-Hill, 1949.

   This text is included because it is the best available source of structural and identification information for commercial woods of the United States.
4. Wexler, A. and W. G. Brombacker, *Methods of Measuring Humidity and Testing Hygrometers,* National Bureau of Standards, Circular 512, Washington, D. C., 1951.

   This paper is an excellent review of the methods for measurement of the moisture in the atmosphere and is particularly useful in conncetion with the design of wood-conditioning apparatus.

A consideration of the testing equipment needed for work in specialized branches of the industry leads to a listing of large numbers of items. Such an inclusive discussion is beyond the scope of this paper. However, certain types of equipment will be included because they have a fairly general usefulness or because of the importance of the test

work for the particular branch of the wood industry.

Plants which utilize an adhesive in their product are especially open to difficulties which can be reduced by an intelligent application of test procedures. In those cases in which the end product is plywood, it is necessary as a minimum requirement to be able to conduct the plywood tension-shear test. For this work, the standard is a shot-type, manually operated plywood test machine which is quite commonly in use. This machine is relatively slow and lacks uniformity due to manual operation. For this reason, whenever the volume of work, or other justifications can be found, the purchase of an hydraulic plywood test machine or the use of special grips in a universal testing machine will give more satisfactory results.

Another important test for glued assemblies is the compression-shear block test. Normally these are run on a universal testing machine using a fixture adapted to the specimen. Because the cost of such a machine is too high for most small plants to consider, it is well to mention that a satisfactory piece of equipment can be manufactured in any machine shop using a rigid frame in connection with an hydraulic jack and pressure gauge. A considerable number of such pieces of apparatus are in use today as a result of the plans which have been distributed through the Timber Engineering Company glue school sessions.

The universal testing machine has been mentioned several times as a standard for test work. As has been noted previously, few of the many models available commercially are within the cost range of a small wood-working plant under ordinary circumstances. However, in the last few years several manufacturers have been producing machines of less than research precision which are cheap in comparison with the usual mechanical testing equipment. In terms of cost complete with a minimum of test fixtures this means that the price will be approximately two thousand dollars and generally nearer to three thousand. Such a machine can carry out shear tests, bending tests on wood, plywood and fiberboard, and also make compression tests on a wide variety of products. In fact, its usefulness is limited only by the ingenuity of the operator, and in the long run, such equipment is worth the initial investment if a serious effort is to be made to control the end product.

One last item is worthy of consideration at this point. This piece of equipment is a standard, student laboratory microscope. A great many lens combinations are possible. In practice it has been found that a useful set of lenses is as follows: 10X eyepiece; parfocal nosepiece fitted with three objective lenses. The focal lengths of the objective lenses are 32 mm., 16 mm., and 4 mm. respectively. With the addition of a few slides and cover glasses, a small quantity of alcohol and a bottle of white Karo syrup it is possible for a plant technician to examine a piece of wood properly. With this information he can make an intelligent correlation of mechanical test results and physical structure.

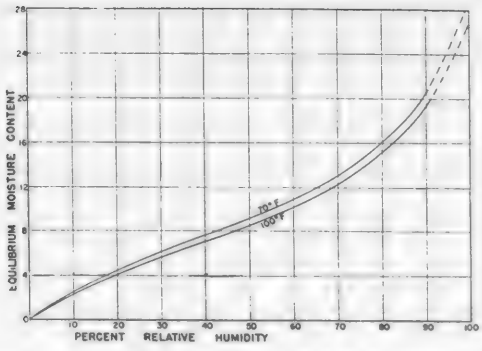


Figure 1.—Curves showing the typical variation of the equilibrium moisture content for wood with the relative humidity of the air at temperatures of 70° F. and 100° F. (adapted from data given in Tech. Note No. 156 of the U. S. Forest Products Laboratory, Madison, Wisconsin, 1952).

Conditioning Equipment

Wood can be conditioned[2] to a uniform and standard moisture content without the necessity of elaborate and expensive air-conditioning equipment. This is possible by the use of a conditioning chamber or cabinet which is of relatively simple and economical design and therefore can be constructed by plant personnel. The relative humidity in such a chamber is controlled either by adding moisture to the air when the humidity is too low or by elevating the temperature somewhat when the humidity is too high. Before describing the construction and operation of such a conditioning chamber in more detail it is desirable to discuss the physical principles involved.

1. **Physical Principles Involved:** Wood is a hygroscopic material in that it comes to a moisture equilibrium when exposed to an atmosphere of a particular relative humidity and temperature. The moisture content of wood under these equilibrium conditions is called the "equilibrium moisture content" (abbreviated E.M.C.) of the wood at that partciular temperature and relative humidity. The E.M.C. of wood varies considerably with the relative humidity and also slightly with temperature. Figure 1 shows the typical variation of the E.M.C. of wood with relative humidity at two temperatures. Individual kinds of wood and also individual pieces of wood vary somewhat from the exact values of E.M.C. given in the figure. Furthermore, the past history of a wood specimen determines its E.M.C. under given conditions. However, these deviations from the curves of Figure 1 are of a minor nature, particularly in the range of moisture contents at which wood and its products are usually tested, and these curves can be used with good approximation for many woods.

The relative humidity of the atmosphere depends upon two factors which are, the concentration of water vapor in the air, and the air temperature. At any particular temperature a given concentration of water vapor exerts a particular vapor pressure which is essentially independent of other atmospheric gases. For each temperature there is a maximum concentration of water which can exist in vapor form in the air. At this maximum concentration the air is "saturated" with water vapor and the vapor pressure corresponding to this condition is termed the saturation vapor pressure. It is identical with the water vapor pressure which exists in the air over the surface of water enclosed in a container at equilibrium with the same temperature. Usually the water vapor pressure in the atmosphere is lower than the saturation vapor pressure. The ratio, expressed as a percentage, of the existing water vapor pressure to the saturation water vapor pressure at the same temperature is called the percent relative humidity, or more commonly, the relative humidity. Figure 2 gives the relationship between water vapor pressure and temperature for various relative humidities.

By use of Figure 2 it is possible to demonstrate how the relative humidity of a conditioning chamber can be lowered below that of the atmosphere in the room surrounding it. For instance, suppose that the room temperature and relative humidity are 79° F. and 80 percent, respectively, (corresponding to an E.M.C. of about 17 percent) and that a relative humidity of 50 percent

[2] Wood conditioning, as defined here, means the controlling of the moisture content of wood which has already been dried. It does not mean kiln-drying nor the type of equipment associated with that process.

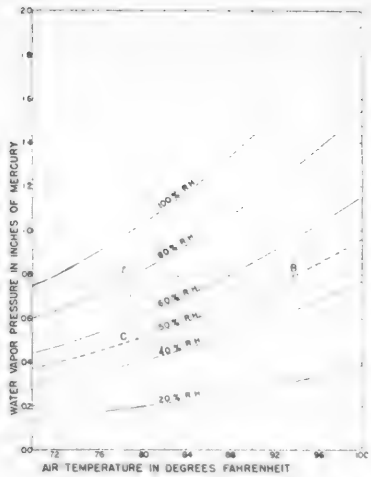


Figure 2.—Family of curves showing the relationship of the water vapor pressure expressed in inches of mercury to air temperature in degrees F. for various percentages of relative humidity. The significance of points A, B and C are given in the text.

(corresponding to an E.M.C. of about 9 percent) is desired in the conditioning chamber. Point A in Figure 2 represents the given room conditions. If vapor pressure is kept constant and the temperature in the conditioning chamber is elevated to 94°, to point B in Figure 2, the relative humidity in the conditioning chamber is decreased to the desired value of 50 percent. Since the vapor pressure was kept constant the water vapor in the chamber has the same vapor pressure as that in the room and equilibrium is established between the two even though the relative humidity difference is 30 percent. The E.M.C. of wood at a given relative humidity changes somewhat with temperature (Fig. 1) but not enough in most cases in the small range of temperatures used here to necessitate correcting for it.

It is possible, of course, to reduce the relative humidity in the chamber from 80 percent to 50 percent without elevating the temperature. This can be accomplished only if the vapor pressure is lowered by removing moisture from the air, that is, by moving from point A to point C in Figure 2. This requires the use of dehumidifying equipment of either the hygroscopic or of the refrigeration type. These are relatively expensive and/or troublesome and will not be discussed in detail in this paper although they are quite satisfactory when properly installed and serviced.[3]

[3] There are at least two types of room dehumidifiers which are commercially available. The mechanical refrigerator type condenses water from the atmosphere on the cold refrigerator coils and then reheats the dried air. The adsorbent type adsorbs moisture from the air by passing the air over or through a hygroscopic material such as a silica gel. Some of the latter type of units are automatically recharged or rejuvenated by passing heated air through the material. Either of the above two types of dehumidifiers can be used in large chambers or rooms if temperature increase is undesirable, but the cost is higher than that of the simple mechanism described in this paper.

2. **Control of Relative Humidity in a Chamber:** A system for controlling the relative humidity in a wood-conditioning chamber consists of two basic components. These are, the humidity sensing element or humidistat, and the humidity correcting element. The humidistat senses changes in the relative humidity of the air and closes a circuit which activates the correcting element. The latter raises or lowers the relative humidity in the chamber in response to the activating signal from the humidistat.

There are many kinds of humidistats such as the hair element, wood element, goldbeater's skin, wet and dry bulb thermometer or thermocouple, infra-red adsorption, electrical resistance hygrometers, etc. These vary considerably in range, precision, sensitivity, stability of calibration, and in cost. The hair element humidistat is quite satisfactory for most purposes where temperatures are in the order of 100° F. and lower, and where the relative humidity at the control setting is between 30 percent to 80 percent. This corresponds to an E.M.C. range in wood from about 6 percent to 17 percent. The hair humidistat is sensitive to relative humidity changes from its control setting of about ±2 percent which corresponds to E.M.C. deviations of about ±½ percent in the wood. Furthermore, hair elements sense humidity changes rather quickly in comparison to most kinds of humidistats. Finally they are nominal in cost (approximately $25), simple in operation, and easily available commercially. If not abused they retain their calibration for some time, but they should be checked from time to time and readjusted if necessary.

The humidity correcting element, for humidification control may consist of an air blower which, when activated by the humidistat, circulates moist air from the atmosphere over an enclosed container of water into the conditioning chamber. The humidifier atmosphere is interconnected to the conditioning chamber by a closed duct system such as is shown in Figure 3. This system has a rapid response time and abrupt cutoff since the blower has little time lag.

For satisfactory humidity control in a wood-conditioning chamber there should be provision for maintaining continuous adequate air circulation. This is important for two reasons. First, it provides constant relative humidity and temperature throughout the chamber, and secondly, it circulates air continuously past the humidistat, thus improving its response characteristics. Air circulation can be most easily accomplished by the use of one or more electric fans, depending upon the size of the chamber. A more efficient system is the type used in a dry kiln where the

Figure 3.—Schematic diagram of a representative humidying apparatus for a wood-conditioning chamber showing the source of moist air and the conditioning chamber. The electric heater A continuously connected to a source of electric power B heats the water C to a desired temperature thus maintaining an elevated vapor pressure in the air space D. When humidification is required the electric air blower E, circulates moist air from the source D to the conditioning chamber through the circulating tubes or ducts F and G. The arrows indicate the preferred direction of air flow.

air is forced to circulate over the entire load of specimens. In any event the humidistat should be located in the air stream.

Construction and Operation of the Conditioning Chamber: In the kind of conditioning chamber described here, the type of construction is not usually critical, provided the range of relative humidity and temperature is not excessive. The chamber itself can be built from materials at hand or easily available in most wood-working establishments. The only important consideration, apart from economy of construction, is that the walls provide an adequate vapor resistance and thermal resistance to the loss of water vapor and of heat, respectively. In most cases ordinary ½ inch plywood sheathing is adequate, although a coat of vapor-resistant paint retards moisture diffusion still further. If lumber sheathing is used a vapor-resistant foil or paper should be used to cover the interior surface. Additional thermal insulation may be desirable in a larger chamber of the walk-in type but this may not be necessary since the temperature differential between the chamber and the room is usually small. The writers found that a 100 watt light bulb maintains the temperature in a 2x2x3 foot cabinet built from ¾ inch plywood at better than 40°F above room temperature, which is a much greater differential than is usually required.

The simplest type of electrical circuitry necessary for maintaining a constant relative humidity in a wood-conditioning chamber of the type described in this paper is given in Figures 4 and 5. The humidistat controls the humidifier blower through a 110 volt electrical relay. The relay may be dispensed with if the electrical power required by

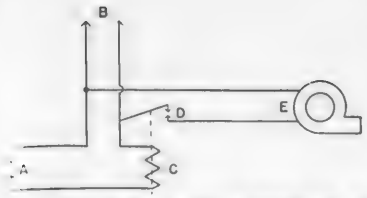


Figure 4.—Electric circuit diagram for the humidification control. The humidistat closes switch A which then applies power-line current from B to activate the relay C, which in turn closes switch D and thus applies power to the humidifier blower E.

blower motor is less than rated power capacity of the humidistat snap-action switch. However the recommendations of the humidistat manufacturer should be followed in this regard. The heaters, which can be ordinary electric light bulbs in most cases, are controlled by means of one or more electric switches. In the example shown in Figure 4 there are two switches. The purpose of these heaters is to keep the temperature in the conditioning chamber always high enough so that the relative humidity in the chamber tends to be lower than the desired conditions without the humidifier operating. The humidifier then corrects the relative humidity to the desired value. The advantage of this system lies in its simplicity and convenience. During the winter months when the relative humidity is usually low indoors the heaters can be turned off if desired. In the summer months they are normally turned on. During the transition periods of spring and autumn some of the heaters are turned on. The humidifier operates in the same manner all year around, and the electrical circuitry is simplified. Some minor adjustment of the humidistat may be necessary when a major temperature change is made in the chamber.

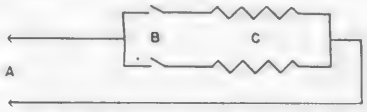


Figure 5.—Electric circuit diagram for the electric heating circuit for maintaining an elevated temperature in the conditioning chamber. The electric power source A is connected to either or both heaters C by manual or thermostatically controlled operation of either or both switches B.

It is, of course, feasible to operate the heaters directly from the humidistats when dehumidification is necessary, and the humidifier when humidification is required. However this results in a period of instability during the transition period of the spring and autumn months and the electrical circuitry is somewhat more involved.

If it is necessary, during the testing of wood, to maintain a lower temperature than that of the conditioning chamber the wood can be cooled relatively rapidly without significant change in its moisture content. This is possible because the heat diffusion coefficient of wood is 100 to 1000 times greater than the moisture diffusion coefficient at ordinary temperatures.

New Methods in Packaging and Handling Plank and Timber[1]

T. S. VEAZEY, JR.

Anaconda Copper Mining Co. Engineering Research Dept., Butte, Montana

New packaging and handling facilities were designed on the basis of time and method studies. Report discusses objectives and results accomplished in changing over to a mechanized handling and unit load system.

STUDIES IN PACKAGING, handling and production of plank and timbers at our Bonner sawmill came about as a result of studies in mechanization at the Butte mines[2]. Some of the procedures adopted at Butte were borrowed directly from the lumber industry; others had to be devised to meet special situations. These included the system of making up small (26 by 38 inch) packages of rough plank of irregular widths for loading onto mine cage decks, and the engineering of special lift trucks with rotating heads and grab jaws.

Receiving, handling and distribution of plank and timbers at Butte tied in closely with production and loading problems at Bonner. When facilities at the Bonner sawmill proved unsuited to the demand of the packaged handling system for the Butte mines, the next step was a mechanization survey at Bonner.

The timber deck at Bonner had been built in the days of horse tramming and low cost labor. Since the structure was old, rebuilding was due in any case. The analysis of production rates and handling systems and the experiments which led to the design of the present plant represent a typical example of applied time and method studies.

Figure 1 shows a generalized flow sheet of material from the mill, under the old scheme. All 3 inch plank and timbers were handled out through the end of the sawmill to roll cases on the timber deck. A trimmer located between these roll cases was used to cut the 5 foot–4 inch and 7 foot–9 inch special lengths of 3 inch mine lagging. Cutoff saws on each of the two roll lines were used for cutting timbers. When flat cars were available, the cut-to-length lagging was dropped from a transfer onto car decks, where it then had to be piled by hand. For stockpiling, or when cars were not available, it was necessary to pile up the lagging on the timber deck temporarily or load it by hand onto a larry car for hauling out along the trestle. There also the material was thrown off by hand, re-piled at the foot of the trestle, throwing aside the broken material to be burned or otherwise disposed of, and later reclaiming from these stockpiles by hand, again one piece at a time.

Long plank and timbers were loaded off either side of the timber deck. To one side, there were skids and a platform which would hold an accumulation while an order was being cut. Some of the load could be slid or rolled down onto railroad car decks. However, about half the material had to be rolled with cant hooks and brute strength up inclined skids.

On the other side of the timber deck a set of transfer chains unloaded direct onto a railroad car, dropping the heavy timber onto the car deck, where it then had to be straightened and piled.

[1] Presented at the FPRS Inland Empire Section Meeting at Missoula, Montana, July 15, 16, 1954.

[2] T. S. Veazey, Jr., "Packaged lumber for the Mining Industry". Proceeding of the 6th Annual Northwest Wood Products Clinic (Spokane). April, 1951.

The Author, T. S. Veazey, Jr., holds a B.S. in geological engineering from Montana School of Mines. He has been employed by Anaconda Copper Mining Co. since 1936 at mining operations in various western states and Mexico. Veazey, a World War II veteran, has been engaged since the war in mechanization of timber handling at Anaconda's Butte mines and research for the lumber dept. at Bonner, Mont.

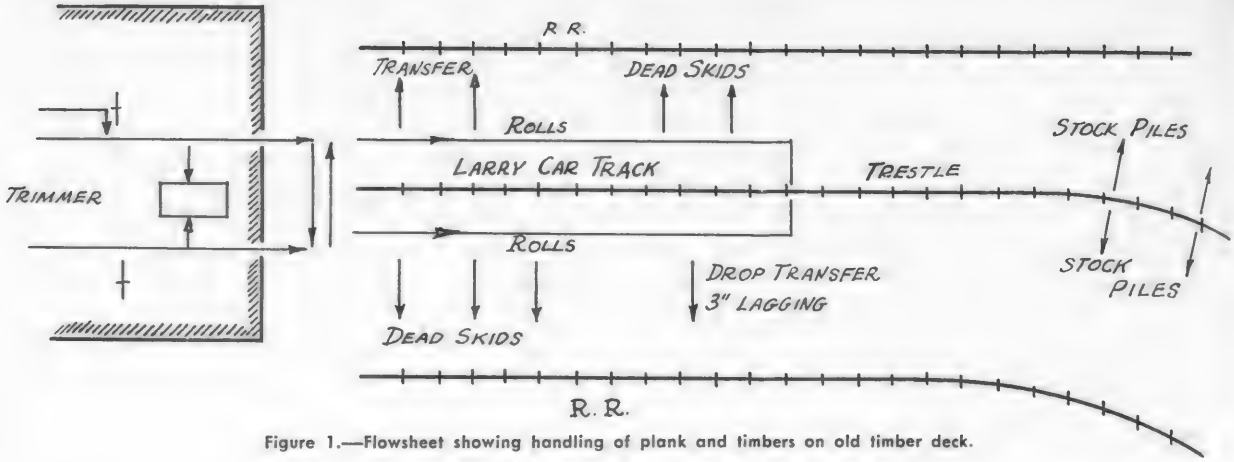


Figure 1.—Flowsheet showing handling of plank and timbers on old timber deck.

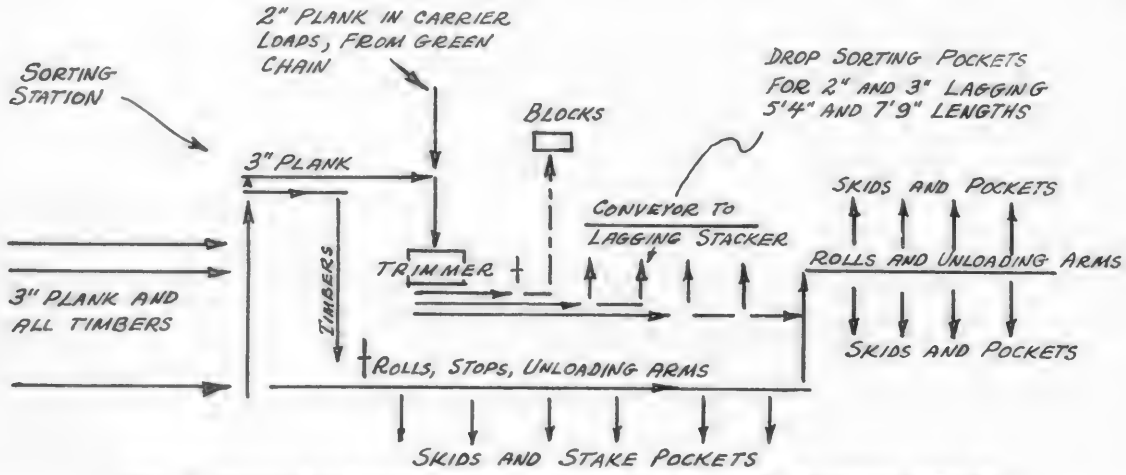


Figure 2.—Flowsheet plan of sorting, cutting, and packaging mine lagging and timbers at new plant.

A considerable amount of 2 inch rough sawed lagging is used at Butte, much of it cut into 5 foot–4 inch and 7 foot–9 inch lengths, random width. Two-inch plank was and still is handled with the main flow of boards and dimension lumber across the grading table onto the green chain. Mining grade plank is marked by the grader and pulled off at the first station on the green chain.

Under the old production and handling system, this was a random pile which was subsequently broken down for cutting to length, using a cutoff saw mounted at a roll line. The cut-to-length lagging was then piled by hand onto railroad cars.

In order to accomplish a change-over to mechanized handling and a unit load system, it appeared that these should be the objectives:

1) Consolidate the handling of 2 inch and 3 inch plank so that all cutting to mining lengths would be done on a single special trimmer. This would necessitate bringing 2 inch plank around from the green chain to the timber deck either by conveyor or in unit loads, since it was desired to continue grading all 2 inch material on the sorting table into mining plank or dimension lumber.

2) Provide a means for accumulating lumber during peak production periods so that when production rate exceeded loading rate, facilities would not be swamped.

3) Make steel strapped unit loads as soon as possible in the handling process, so as to eliminate manual handling one piece at a time.

4) Arrange for efficient cutting and loading of short mining blocks (from trim ends of timbers and 3 inch plank), and short heavy timber items such as mine ties.

5) Bring as much of the operation as possible under cover so as to eliminate the previous interference from snow and ice.

6) Provide sufficient loading space and paved yard area for lift truck operations so that loading and shipping operations would both be independent of railroad switch engine service.

A survey over a period of several months indicated that approximately two-thirds of the material to be handled would be cut into special mining lengths, such as 5 foot, 5 foot–4 inch, and 7 foot–9 inch, most of this being 2 inch and 3 inch plank. The remaining plank and timber would be in 16 foot or other commercial lengths. Detailed time studies were then made to study rates of flow of material, together with labor requirements. Shipping records were analyzed to determine the greatest number of items loaded out during any single day. Data upon which the new plant design was based included:

Estimated total requirements of lagging and timber would amount to approximately 2,220,000 board feet per month.

Facilities would have to be capable of handling three railroad cars per shift. Maximum number of unit loads would be occasioned if entire shift output were 5 foot–4 inch lagging. At 32 units per car, 3 cars would take care of 96 unit loads per shift.

This indicated that sorting, packaging and loading facilities must be capable of handling 2 inch lagging at a rate of 20 pieces per minute 3 inch lagging at a rate of 13 pieces per minute.

Shipping records showed the largest number of items handled in one

Manual handling on old timber deck.

Trestle extending from old timber deck to yard area, and hand-piled stocks of timber.

two-shift day was 18, and that the maximum number of pieces involved was 952, in a quantity of approximately 50 thousand board feet.

A number of methods of sorting and accumulating were considered. Complete mechanization would have been desirable, however too costly. Therefore, mechanization was concentrated on the items making up the greatest volume and the greatest number of pieces, that is, the cut-to-length 5 foot–4 inch, 7 foot–9 inch, etc., together with mine ties and chute braces. A "semi-mechanized" system was devised for sorting timbers beyond the cutoff saw, unloading them from the roll line onto accumulating skids where they could then be dropped into stake pockets by two men, into unit loads for steel strapping. Figure 2 illustrates the flow plan.

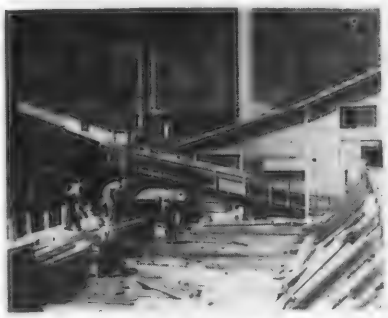
In this plan, the roll lines carrying 3 inch plank and all timbers discharge onto a cross transfer. Here by means of sorting arms the 3 inch plank is separated from the timbers. Timbers are transferred back across the mill to the east roll line on which is located an air-operated cutoff saw. Outside the east wall of the mill are a number of sorting and accumulating skids, and the stake pockets for making up unit loads. Kickers which unload timber from the rolls into these pockets are under the control of the cutoff saw operator. At the end of the mill another transfer is provided which discharges onto rolls extending beyond the mill, with four additional accumulating and sorting pockets on either side.

Inside the mill, 3 inch plank are conveyed on a rubber belt from the sorting point to a transfer ahead of the lagging trimmer. At this point, in the west wall of the mill, a transfer has been installed onto which carrier loads of 2 inch plank may be placed by a lift truck. These are brought around from the green chain by carrier.

The trimmer was specially designed to cut mining lengths. The transfer ahead of the trimmer is sectionalized, with a set of sorting arms and rolls beneath that make it possible to drop out 2 inch or 3 inch plank if desired, routing this to the timber transfer and cutoff saw. Beyond the trimmer, an air-operated sorting baffle under control of the trimmer operator sorts 2 inch from 3 inch cut-to-length lagging, each dropping onto its own conveyor belt.

Five foot–4 inch, 5 foot, and 7 foot–9 inch lengths must be cut from random length plank in order to utilize as much as possible of the lumber length. Thus two or more lengths may be cut from a single plank. Various sorting devices were considered for separating these, including conventional drop sorting from a transfer, as well as limit switches which would automatically actuate kickers. The simplest device appeared to be a lengthwise drop sorting arrangement in which one or more of the live rolls are left out of the roll case. With proper roll spacing, a piece of 5 foot–4 inch lagging will "dive" down through the rolls, while the 7 foot–9 inch length will bridge the gap and continue to the next sorting gap of its own momentum. Sixteen foot or other commercial length plank will bridge both sorting gaps and be discharged onto the transfer at the foot of the mill. A full scale mock-up of such a sorting device was actually built in the shop and tested to prove the soundness of this design principle, before deciding to adopt it.

The next problem was to make the sorted lagging pile up in an orderly manner on the accumulating chains on the floor of each pocket. Naturally, a piece of lagging dropping through a roll case endwise would slide endwise down the skids, ending up in a jumble or a jackstraw pile. This was overcome by installation of a set of angle irons or "steps" on the inclined skid surfaces which tend to catch the planks as they fall, straightening them out. These are followed by a swinging baffle gate. The



Hand piling timber from skids onto railroad car.

Experimental setup beside old timber deck to work out details of method for accumulating and piling timbers into unit loads.

Experimental mock-up of roll line with sorting gap. Plank traveling from right to left dives into opening, is straightened in its fall by angles or steps on inclined skid surface.

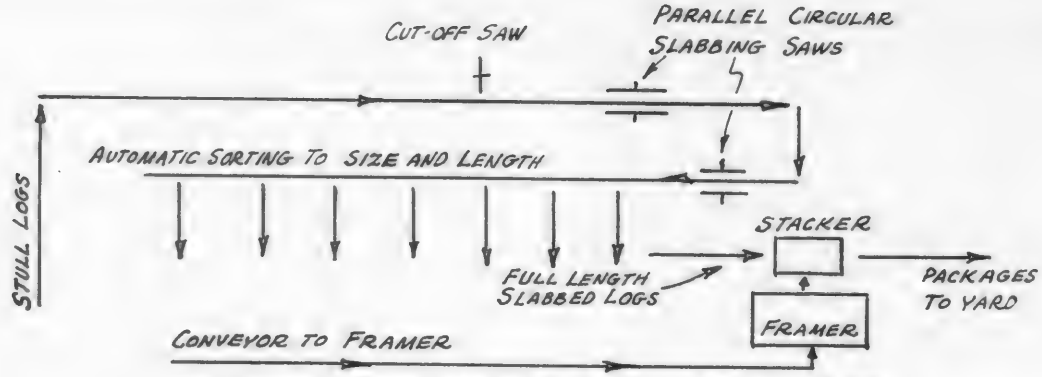


Figure 3.—Flowsheet of new mine timber cut-up, slabbing, and framing plant.

View looking down on sorting gaps in roll line.

Breaking down lagging from deck chains to conveyor ahead of stacker.

General view of lagging sorting pockets. Note orderly piles of lagging accumulated on deck chains.

net result was an orderly piling up of the sorted lagging so that the accumulation on the floor chains could be 2 or 3 feet deep. This makes it possible to accumulate a quantity of three items while packing a fourth; or during a period of light production, to accumulate all items without operating the stacker.

A common conveyor belt runs along the front of the several accumulating pockets. The accumulated piles of lagging are broken down one item at a time, to feed via this belt to the stacker, where unit loads of approximately 54 inches wide x 40 inches high are packaged.

Mine blocks, cut from trim ends of 3 inch plank and timbers, are conveyed into hopper boxes. These boxes are designed for lift truck handling and open at one side for dumping into the top of a regular wood car.

The results envisioned when this plant was proposed have all been realized:

1) Plank and timber items can now be sawed for best utilization both of log sizes and of species, without regard to availability of railroad cars, since handling is no longer a problem.
2) Movement of plank and timbers to the planing mill has been greatly facilitated.
3) Lift truck handling has made it possible to accumulate slow moving items without tying up the loading skids.
4) Manual handling in the yard has been eliminated, and labor efficiency greatly increased.

Engineering of the new timber deck and supervision of construction were performed by the firm of W. H. Rambo, Industrial Plant Engineers, Portland, Oregon.

Mine Timber Slabbing and Framing Plant

The success of the program for mechanized handling of sawed lagging and timber items indicated that some attempt should be made to package the round timbers used for posts, caps, and girts in the Butte mines. A good many years ago the use of sawed 12 by 12's, 10 by 10's, etc., had been discontinued for obvious reasons of economy. However, round timbers do not lend themselves to packaging in small unit loads; nor could the cost of a return to sawed timber be justified. The answer appeared to be to slab the timbers so that they would "face up" just sufficiently to be piled and strapped into packages. A small quantity of timbers slabbed in this manner was made up, and the success of the handling experiments was immediate, indicating that substantially complete mechanization of all timber handling at Butte would become possible.

It was also evident that a change to slabbed timber would make possible much greater uniformity in size. There is a limit to the practicability of sorting in the woods, and existing mill facilities for sorting were also limited. These factors plus the natural taper of the logs resulted in differences of 6 inches or more in timber diameters for the same items. Obviously, the excess timber was being wasted. For best utilization, the objective should be to cut a log on the mill deck into the sizes and lengths for which it is best suited, whether this be, for example, two 8 by 8's and a 10 by 10, or part mining timber and part saw timber. This then was the basis for the mill design finally adopted.

It was necessary to determine by actual test how such slabbed timber would compare in underground service with the round timber it was intended to replace. In full scale operating trials it was established that timbers slabbed to 8 by 8 size would be strong enough for ordinary stoping operations, and that slabbed 10 by 10's would be suitable for heavier ground and for tunnel type timbering. A complete new system of framing horns and tenons was devised to suit the slabbed timber. Species were also compared in the course of these tests, and it was found that green lodgepole pine could be used interchangeably with fir and larch.

It developed that handling timber in bundles made for much better supply service to the working places. For the miners, timber was easier to handle, being of uniform size. And because it was square, it was easier to block to the ground. Chute braces and lining went into place better. The net result was a startling improvement in mining efficiency. It is anticipated that the gain

Left photo shows new timber deck and unloading of 10 x 10's, by remote control, to one of six accumulating pockets. Right photo shows west side of new building, general view of accumulating skids and loading pockets. Left foreground, two sets of deck chains for short material cut in volume. Right center, sawed timbers are piled into unit loads, for steel strapping.

in underground efficiency may well prove to be more important than the direct savings in materials handling alone.

The next question was one of how to slab the timbers. Various schemes were considered, including a horizontal resaw with divided bed and merry-go-round, twin band saws, Swede and cant gangs. Time and cost studies at the Bonner sawmill showed that the cost of slabbing on the head rigs would be prohibitive, and that whenever crooked or butt logs were put on the carriage, the slabbing cuts were so heavy as to result in very poor recovery. Finally, after extensive study, attention was directed to the Shannon mill near Eugene, Oregon, where studs were being sawed on a parallel circular saw outfit with chain feed bed, and with saws quickly and easily adjustable for distance apart by means of one operating control lever. This is the principle which has served as the basis for design of the equipment in the new mill at Bonner now approaching completion. Two such units are located in tandem, with the cut-to-length material passing through the first set of saws, then being turned onto the flat side to pass through the second set of saws to complete the squaring-up.

The flow sheet of the new mill is shown in Figure 3. Logs will be cut according to the sizes and lengths for which they are best suited, on the cut-off saw at the head of the mill. From the two tandem sets of slabbing saws, the slabbed cut-to-length pieces will be conveyed to the sorting pockets. Sorting will be done automatically, by means of limit switches which are actuated according to the diameter and length of the pieces. These accumulating chains in turn will unload to another conveyor, to the framer.

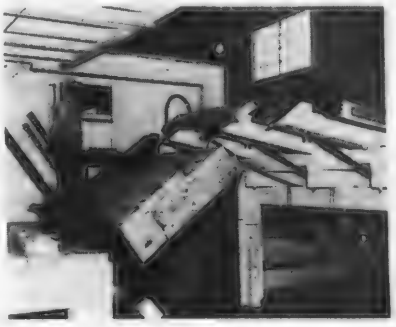
The framer was specially engineered for the job, to frame a horn on one or both ends of a piece of timber. It is adjustable for length, one end being movable, and the framing saws can be positioned to vary the size of the horn. Framed timbers discharge onto a stacking jig, and completed unit loads are set onto a roll line in the usual manner for banding and further handling by lift truck.

The decision to locate this new mine timber slabbing and framing plant at Bonner was made after analysis of the timber supply factor, all the various cost items, and other factors involved in plant location. Some of the timber for this plant will be logged in stull sizes, principally in the 8 inch to 12 inch size range. It is intended also to utilize low grade logs, tops, and a certain amount of other small log material which might otherwise be left in the woods. This portion of the timber will be shipped with the sawlogs, unloaded into the sawmill hot pond, and taken out of the mill at the cutoff saw ahead of the east rig. This system of handling will make it possible to utilitze shorts, broken ends, etc., for mine timber. From the sawmill, these logs will be transported by a merry-go-round onto a sorting conveyor and unloaded into pockets according to log diameter. Two Pettibone–Mulliken loaders have been purchased for log handling and will carry these logs either direct to the framing plant or to stockpile. These machines are also suitable for unloading stull logs from trucks.

There is a distinct possibility that the slabbing mill will prove suitable for sawing cants, which can then be sawed into dimension lumber and boards either in a gang or resaw. (Since the plant was not yet completed or in operation at the date of the meeting, there has been no opportunity to evaluate that possibility.)

Another result of locating the plant at Bonner will be the consolidation of all waste wood residues at one plant, a factor which will be important in future years. Provision was made for the installation of a chipper when, ultimately, whole log barking and chipping for pulp or other by-products may be adopted.

Air-operated swing cut-off saw. From this position, operator controls stops and unloader arms to pockets outside of building.



Inclined stacker, piling unit loads of mine lagging.

It is expected that this new plant will make possible better utilization of timber for mining purposes, and better recovery of material which would otherwise go into low grade saw logs. Mill waste will be consolidated with present sawmill waste. Important savings are expected in cost of production and materials handling, and even more important savings through better efficiency in underground mining operations.

Around the World in Forest Products Research and Development by G. M. Hunt

Forest Research Institute and Colleges, Dehra Dun, India[1]

JAI KISHEN

Publicity & Liaison Officer, Forest Research Institute & Colleges, Dehra Dun

THE FOREST RESEARCH INSTITUTE and Colleges is one of the leading centers of forestry education and research in the world. Under the control of the Ministry of Food and Agriculture, its administrative head is called the President. Educationally, it trains both rangers and forest officers for the whole country; while on the research side the work is primarily to solve the forestry problems peculiar to India. The Institute also admits students and workers from the neighboring countries for technical training. In 1951, it was recognized by the Food and Agriculture Organization of the United Nations as a center for training in forestry for entire South East Asia.

Research work is organised under two main heads—biological and utilization or forest products. Research on the biological side pertains to the rearing and protection of forests and is carried out in the Silviculture, Botany Mycology and Entomology Branches while that on the forest products is undertaken in the Wood Anatomy, Wood Seasoning, Wood Preservation, Composite Wood, Timber Mechanics, Timber Engineering, Minor Forest Products, Chemistry of Forest Products and Cellulose and Paper Branches. The Institute also has Service, Statistical and Publicity and Liaison Branches.

The number of officers in the Forest Research Institute and Colleges is at present 72. Of these 20 are in education, 47 in research, and 5 in administration.

New Forest

The New Forest Estate, in which the Institute is located, is situated four miles from Dehra Dun. About 1100 acres in area, it provides ample space for the future expansion of the Institute. New Forest is a residential colony as well, since almost every worker in the Institute is provided with appropriate housing accommodation. It has a high school, hospital, co-operative society, clubs, playgrounds and a post and telegraph office. A Government bus service connects it with the town of Dehra Dun.

History of the Institute

The growth of the Forest Research Institute and Colleges has kept pace with the development of forest policy in India. Before the advent of the British rule and a few decades after there was no forest policy in practise, nor was it considered necessary. The first real step taken by the Government in this direction was the creation of the post of the Inspector General of Forests in 1864 with duties to advise the Government of India in laying down the general forest policy and to organize a department to carry out this policy.

On the recommendations of Brandis, the first Inspector General, the Government in 1867 introduced a system under which the probationers selected for the Senior Forest Posts (later on called the Indian Forest Service) were trained in forestry in Europe. In India, too, a forest school was started at Dehra Dun in 1878 by the Government of the then North West Province for giving a two-year course of training to rangers. The school which was taken over by the Central Government in 1884 and named as the Imperial Forest School was the forerunner of the present Forest Research Institute and Colleges.

Except for the creation of a post of Reporter on Economic Products in 1887, little attention was paid by the Government of India in the last century to the need for research in forestry. It looked upon the forests as a commercial concern. In 1901 the Government of India ordered the formation of the Agricultural Research Institute. The Inspector General of Forests, Eardley Wilmot, pressed the Government for the opening of a center for forestry research as well, and succeeded in getting the necessary sanction. So, in 1906, a Forest Research Department was established in the Imperial Forest School and the latter redesignated as the Imperial Forest Research Institute and College. The research posts created were, 1) Imperial Silviculturist, 2) Imperial Superintendent of Working Plans—afterwards transferred to the office of the Inspector General of Forests, 3) Imperial Forest Zoologist, called Entomologist since 1922, 4) Imperial Forest Botanist, 5) Imperial Forest Economist, called Utilization Officer since 1937 and 6) Imperial Forest Chemist.

Accommodation in the old school was found inadequate for the expanding activities of the Institute. In 1914, therefore, the Research Department and the Provincial Forest Service Training Class (which had been introduced in 1912) were shifted to Chand Bagh, a 47 acre estate purchased for the purpose in Dehra Dun.

Expansion

During the first World War, which came shortly afterwards, both the staff and equipment of the Institute were found insufficient for meeting the various demands made on it. The Industrial Commission of 1916–18 also laid stress on the necessity of expanding the activities of the Institute for the development of forest industries. Accordingly in 1920–21 the Forest Economy Branch was reorganized and new sections of Wood Technology, Minor Forest Products, Paper and Pulp, Mechanical Engineering, Wood Working, Wood Seasoning, Timber Testing and Wood Preservation, were added to it. The beautiful site now occupied by the Institute was bought. Experts were sent abroad to order up-to-date laboratory and workshop equipment; and construction of the buildings which took several years to complete, was started immediately. Officially the institute occupied the new buildings in 1929. This arrangement continued till the beginning of the Second World War.

[1] A contributed paper.

The Second World War again found the Forest Research Institute inadequately organised for meeting its increasing demands. Consequently at the close of the war another reorganisation scheme estimated to cost about six million rupees and to be completed in the next five years, was drawn up. However, due to financial stringency prevailing in the country, the scheme could only be partially implemented. A Statistical Branch and a Publicity and Liaison Branch were established in 1947. At the same time the Utilization Branch was split into a number of independent branches in order to afford full scope of development in each field of investigation. In 1950 a few branches were bifurcated and in 1953 a new Timber Engineering Branch was opened.

Improvement effected in the equipment under the reorganisation scheme is noteworthy of mention. A modern plywood plant including a slicer was erected for the Composite Wood Branch. A laboratory and an automatic-controlled experimental kiln was set up for the Wood Seasoning Branch building to house another laboratory and a new paper plant received recently by the Cellulose and Paper Branch, was constructed. The paper plant is being set up. New machinery was also installed in the Iron Workshop, the Saw Mill and the Wood Workshop.

Forest Research Institute, Dehra Dun, India.

Research Program

All research in the Institute is carried out according to a quinquennial program. The Government of India in 1939 formed the Central Advisory Board on Forest Utilization for coordinating the research program of the forest products branches of the Institute with the needs of commerce, industry and the general public. At periodic meetings of the Board the program of research of the forest products branches is submitted for advice. Since the Advisory Board could not meet frequently an Executive Committee of the Board was instituted in 1952 to carry out the work of the Board continuously.

In the utilization of forest produce for the industrial development of the country, the Forest Research Institute has made many significant contributions. The establishment of some very important industries has been made possible only as a result of the investigations carried out at the Institute. A perusal of the scope of work of the various forest products branches of the Institute and their achievements bears this out.

Wood Anatomy Branch

Wood Anatomy is rightly described as the fundamental basis of timber utilization. Not only do the anatomical features of a wood identify it but they also provide a broad idea of its physical and mechanical properties. The branch has carried out anatomical studies on Indian woods, from the point of view of their utilization. These studies have a special significance for India which contains only a few well-known timbers and a large number designated as jungle woods. For the purpose of reference the branch has one of the finest timber collections in the world.

The branch handles a very large number of enquiries received from industries for advice on the identification of timbers or their suitability for specific purposes. It is also bringing out hand books on the identification and properties of timbers found in the various States. One for the Punjab and another for West Bengal are already out.

Composite Wood Branch

This branch investigates the problems of *improved wood* like compressed wood, wood impregnated with resins or chemically modified, laminated wood and the combination of all these types. The investigations are helpful in overcoming the disadvantages of natural wood, up-grading inferior timbers and in providing a product exactly suited to any requirement.

The work of the branch is of immediate interest to the railway, aircraft, telegraph and telephone, adhesives, plywood, sports goods, textile, etc., and several other industries.

The work of modern adhesives had greatly extended the use of *built up* (plywood, laminated wood and boards) for technical, architectural and decora-

Poles, posts, and billets treated with preservatives undergo durability tests.

Timber Testing Laboratory at the Forest Research Institute, Dehra Dun, India.

tive purposes. The branch has developed satisfactory adhesives from various proteins, seed cakes and cocoanut shells, etc., and is actively engaged in the production of building boards from bamboos, veneer strips and wood and agricultural wastes.

Wood Seasoning Branch

The Wood Seasoning Branch has designed a number of air seasoning sheds and seasoning kilns. It has carried out investigations on the air and kiln seasoning of various Indian timbers, railway sleepers, poles, bamboos, etc.

For the utilization of Indian timbers for industrial purposes, the branch has devised 3-ply solid jute mill bobbins in which mango and toon are used thereby cutting down imports almost entirely and saving foreign exchange to the extent of 5 million rupees in this item alone. It has found suitable woods for textile mill bobbins and battery separators and has evolved a treatment for improving the whittling properties of deodar and thus rendering it suitable for making good quality pencils.

The branch is equipped with half a dozen different types of seasoning kilns. It advises forest departments and timber industry about the installation of kilns suited to their requirements.

Wood Preservation Branch

Among the very large numbers of tree species in the Indian forests, there are only a few which supply durable timbers. If the material from the rest could be used, the timber shortage in the country would be considerably reduced.

For proper industrialization of the country, steel is required in a very large quantity. Since India's output of steel is far below even her present demand, substitutes for steel have to be found; timber is one.

Research carried out in this branch proves that the service life of perishable woods can be increased five to ten times and they can be used in place of steel for various purposes. *Ascu* water-soluble preservative was developed in this branch, which has also done work on the preservation of thatch and bamboo toward use as low cost house-building materials. Recently the branch had devised a portable plant for giving preservative treatment to green bamboos and light timbers. The branch is also equipped with pilot plants for preservatively, treating timbers of all types.

In 1952 the Preservation and Seasoning branches started the Timber Dryers' and Preservers' Association of India, to bring together research workers, industrialists and consumers of treated and seasoned wood.

Timber-Engineering Branch

The quantity of timber required for structural purposes is far more than used anywhere else. Economy in the use of timber for this work is of paramount importance. The branch prepares designs of economical timber structures especially those using small timber specimens, and also investigates the strength properties of these structures.

Timber Mechanics Branch

Rational timber utilization requires that the right species should be used for a particular job. It is necessary to know the various strength properties and other physical characteristics, like density stability of shape, etc., of timbers. The branch collects data on these lines in conformity with international practice and deduces from this data the possible uses to which a timber can be put. The work of the branch is of great help in finding the suitability of our little known species for commercial purposes and as substitute for imported woods.

The branch has evolved wooden disc dowel joints which can be used cheaply in place of wire-strips, gussets and belts commonly employed in wooden structures. It has shown that cheap timbers like mango and *salai* can be used for ammunition boxes in place of teak. The branch has a well-equipped timber testing laboratory.

Cellulose and Paper Branch

This is the only place in India where organised research is being done on the utilization of forest produce and industrial and agricultural wastes for the production of pulp, paper and boards.

The manufacture of paper in India depends mainly upon bamboo and *sabai* grass for raw materials. Recent work done in the branch on bagasse (which is available in large quantities and at present burned) has been taken up for commercial exploitation for the production of good quality paper.

The special feature of the branch is that it undertakes to impart training in paper and pulp technology to the apprentices deputed by the paper mills and the government departments and publishes a Quarterly Technical Abstract containing information for the benefit of the paper industry.

Minor Forest Products Branch

Besides timber and fuel wood there are numerous minor forest products which play an important part in the economy of our country. They include grasses, bamboos, canes, medicinal herbs, essential oils, gums, resins, etc. India exports Rs. 40,00,00,000 worth of this material annually.

This branch is engaged in economic research on these plants covering their distribution and availability, methods of collection, extent of trade, scope for demand, grading, marketing, etc. It also undertakes experimental cultivation of promising exotic and indigenous plants. Among the achievements of the branch may be mentioned the establishment of artemisia and santonin industry in India, research on improved methods for charcoal manufacture including the designing of a portable kiln and extraction of camphor from *tulsi (Ocimum kilimandscharicum)*.

Chemistry Branch

The Chemistry of Forest Products Branch deals with chemical investigations of forest produce and the study of the properties and uses of their constituents. The branch also works on the development of economical methods of extraction and isolation of marketable products from forest produce.

The researches carried out in this branch have resulted in the establishment of a number of industries in the country as, production of turpentine and rosin, and more recently, sizing material for the jute and textile mills from tamarind kernel powder.

Direct Contact

There is one more activity of the Institute worth mentioning. It is the direct contact, which the officers of the Institute have with the government departments, universities, industrial and technical organisations, traders, factory owners, cottage industry centers, etc. They deal with a large number of enquiries received from them for technical guidance. The officers of the Institute give personal attention to the numerous visitors coming for information, attend various meetings as technical experts, etc. The Institute also undertakes to provide research facilities to the university students and imparts technical training to the apprentices and deputed by the industrial concerns and government departments.

Publications

The Institute is also actively associated with the publications of Quarterly Bulletin of the Timber Dryers' and Preservers' Association of India, Composite Wood and Indian Forester —journals issued for the benefit of wood-based industries and forest departments of the States. The other publications of the Institute are issued in the form of Monographs, Forest Records, Forest Bulletins, Forest Leaflets and Pamphlets, which can be had from the Institute or from the Manager of Publications, Civil Lines, Delhi.

Abstracts From Current World Literature

Properties of Wood

Ivanov, Ju. M. Novaja harakteristika procnosti drevesiny i metody ee opredelenija. [A new characteristic of wood strength, and methods for its determination.] *Trud. Inst. Les.* No. 4, 1949 (34–45). 4 refs. [Russ.]

Introduces a new characteristic of strength, namely the (lower) limit of plastic flow (l.p.f.), defined as the stress beyond which plastic flow, a special forum of deformation, appears. Plastic flow can be observed in compression, tension, shear, bending, torsion etc., hence it is an essential characteristic of wood. Whereas at loads below the l.p.f. wood is characterized by constant elastic properties and resistance to the external load, the mechanical state of wood at loads exceeding the l.p.f. is characterized by a rapid increase of elastic deformations and by the development of irreversible plastic-flow changes that result in the inevitable failure of the wood. The l.p.f., can be determined by the usual sustained-load tests only to an accuracy of ± 10%; moreover, this method requires a very long time and the use of 10–15 specimens of identical properties. A quick determination of the l.p.f. is, however, possible, based on the relationships established by the author for the total deformations of wood. [Forestry Abstracts, V. 14, No. 4]

Runkel, Roland O. H. and Witt, Herbert. The thermoplastic behavior of wood. III. The water and alcohol-soluble components in heat-plasticized wood. The result of a paper chromatographic investigation. (Inst. Forest Management, Reinbek, Ger.). *Holz Roh- u. Werkstoff* 11, 457–61 (1953); cf. C. A. 45, 9855e.

Beech sawdust (23% lignin and 17.25% pentosan as furfural (I) was treated with $NaClO_2$ to give products (II) with 3.7 and 11.5% lignin and 21.1 and 17.65% I, resp., and with dil. H_2SO_4 to give products (III) with 27.8 and 33.6% lignin and 10.5 and 4.5% I resp. II and III were pressed at 250 kg./sq. cm., 180°, and 7.5% moisture content, to boards of d. 1.40 g./cc. Boards made with II had high bending strength, high 28-day water absorption, and high H_2O-sol. content. Boards made with III had low values for bending strength, 28-day water absorption, and water-sol. content. Interparticle bonding is thus promoted by a high I content in the pulp. Water resistance is assocd. with a high lignin content. Hot-water exts of boards contained glucose, xylose, uronic acids, and phenolic derivs., as detd. by chromatography. The latter increased as the lignin content increased. H. Tarkow. [Chem. Abs. V. 48, No. 10]

Krpan, Juraj (Univ. Zagreb, Jugoslavia). The fiber saturation point of beech, oak, fir, and spruce. *Holz Roh-u. Werkstoff* 12, 84–91 (1954).

Krpan reviews critically past methods for measuring the fiber satn. point (I) of wood. He describes detailed study for measuring I by volumetric shrinkage (II) and compressive strength-moisture content relationship (III). With species which contain readily volatile materials, III is recommended. Values given by II seem to depend on specimen size. With oak specimens varying in size from 2- to 5-cm. cubes, I (arithmetic av.) decreases progressively from 24.5 to 20.5%. (Standard deviation is 1.5%.) I is highest for trunk wood in contrast to root and branch wood. [Chem. Abs. V. 48, No. 15]

Anon. Target: a wood that won't warp. *Chem. Week* 75, no. 17: 44 (Oct. 23, 1954).

Efforts for imparting dimensional stability to wood are reviewed; so far, not one of the suggested procedures is completely satisfactory for widespread application. According to Stamm, the most satisfactory solution would be the promotion of cross-linking between the cellulose chains or other components of the wood, provided the correct chemical could be found. Formaldehyde would give the desired results; however, the acid (hydrochloric or nitric) needed to catalyze the reaction degrades the wood with a serious loss in strength. [Bul. Pap. Chem. V. 25, No. 3]

Research

F. D. Silvester. A conditioning cabinet for small test specimens. (Timber Development Association). *Wood*, Vol. 19, No. 9, September 1954.

The conditioning of small clear specimens of timber to the correct moisture content for testing is an essential part of test procedure and it must be done reasonably accurately if reliable test results are to be obtained. Conditioning or humidity cabinets produced commercially are designed to cope with highly intricate and complex problems and are too expensive for the small firm. The author has therefore designed and built his own cabinet at a cost of under £100 and he describes it in this article.

The cabinet measures 1ft. 8in × 3ft 3¼in × 2ft 8in and accommodates six 18in square shelves. A temperature range of 60–140° F and a humidity range of 50–90% can be obtained. It is said to give remarkably good results for the purpose for which it was designed. [F.D.C. Tech. Bul. V. 4, No. 23]

Applied research on wood technology in Japan. *Wood Ind., Tokyo* 9 (1), 1954 (4–49). [Jap.]

This number is devoted to applied research on wood technology in Japan for 1951–52, with short reports from workers in the Ministry of Agriculture and Forestry and 4 other Ministries. Subjects include: design and preparation of fibreboard chippers and defibrators, veneer edge-gluers, preparation of bleached pulp, and hardened laminates. There is a classified list of current literature, largely Japanese, German, American and English. [For. Abs. V. 15, No. 3]

Glues and Gluing

Luttgen, C. Technology of adhesives. Wilhelm Pansegrau Verlag, Berlin–Wilmersdorf. 1953. pp. [3 +] 426. [G.]

A comprehensive survey of patents and recipes for synthetic resin glues, and glues from cellulose derivatives, proteins, starch and dextrin, and other raw materials, is followed by a discussion of gluing methods, including a section on wood gluing. [For. Abs. V. 15, No. 3]

Napier surface heater. D. Napier and Son Ltd.

A system of surface heating, originally developed for de-icing on aircraft, may be of value as an alternative method of mains or low-voltage resistance heating as an aid to glue-setting. The method of building up the heating element is as follows. First the surface of the mould is lightly roughened to provide a key for the base insulation, and flush terminals for the heat element are secured in position. The mould is then sprayed with a layer of resin to provide a smooth surface and thermal and electrical insulation. The heating element itself is applied by spraying metal to the thickness and in the pattern required by the job in question. This is covered with a thin coating of resin to provide adequate electrical insulation but the minimum of resistance to heat transfer. Thermostatic control can be built in.

The preparation of abstracts from world literature in many languages is so highly specialized and costly that the Forest Products Research Society has no abstracting service of its own. For the abstracts in this issue of the JOURNAL the Society is indebted to the respective abstract journals indicated, from which they have been selected with the kind permission of the editors. Readers wishing information in addition to that given in these abstracts should consult the original articles referred to. Copies or additional information can not be supplied by FPRS or the abstract journal. The journals from which abstracts are published in this issue are as follows:

BULLETIN OF THE INSTITUTE OF PAPER CHEMISTRY; published monthly at Appleton, Wisconsin by the Institute of Paper Chemistry, subscription price $25 per year. This Bulletin publishes over 3,600 abstracts per year on subjects of interest to manufacturers of pulp, paper, fiber board and allied products.

CHEMICAL ABSTRACTS, published semimonthly by the American Chemical Society, Executive Office—1155 Sixteenth Street, NW, Washington 6, D. C., subscription price $60 per year plus postage. This abstract journal publishes many thousands of abstracts annually with broad coverage of world literature in the entire field of chemistry and allied subjects.

FORESTRY ABSTRACTS, published quarterly by Commonwealth Agricultural Bureaux, Farnham, Royal, England, subscription price $8.40 per year. The abstracts are prepared by the Commonwealth Forestry Bureau, Oxford, England, and include a Forest Products and Utilization section. This section contains about 1,200 titles and abstracts per year from literature in some 30 languages, covers all aspects of forest utilization.

TECHNICAL BULLETIN OF THE FURNITURE DEVELOPMENT COUNCIL is published bimonthly by the Council at 11 Adelphi Terrace, London W. C. 2, England. The Technical Bulletin publishes hundreds of abstracts and reviews from world literature annually, relating to the various phases of the furniture manufacturing industry. Subscription price is $5 per year.

The maximum continuous operating temperature recommended is 100°C and the wattage loading can be varied between 0.6 and 50 watts per sq in. The loading can be varied from one part of the heater to another, for example, the heating intensity applied to an engine nosing was graded from 4 to 10 watts per sq in. [F.D.C. Tech. Bul. V. 4, No. 23]

Mensuration

Vuokila, Y. Havaintoja puiden luvussa syntyvista virheellisyyksista. [Observations on inaccuracies in calipering trees.] *Metsät. Aikak.* 1952 (12), (357–8). [Fi.e.]

A study was made in 18 sample plots on the errors in volume resulting from inaccurate determination of breast height; the volume of standing trees was determined by Ilvessalo's volume tables [see *For. Abstr.* 10 (No. 777)]. Trees were calipered at 1·0, 1·3 or 1·5 m. Generally, calipering at 1 m. gave an average error of 3·8% in the stand volume, and measurement at 1·5 m. an opposite one of the same magnitude. This means that a systematic error of 10 cm. in the measuring height causes an average error of 1–2%. On one sample plot of exceptionally poorly-formed stock, however, the volume error was 22·6% when diameters were measured at 1 m. [Forestry Abstracts, V. 14, No. 3]

Pathology

Enkvist, T., Solin, E., and Maunula, U. (Univ. Helsingfors, Finland). Pine wood decayed by brown rot. *Paperi ja Puu* 36, No. 3, 65–8, 86 (1954) (in English).

Brown rotting of wood by various fungi decomp. the carbohydrates and leaves residues high in lignin. Scotch pine (I) (*Pinus silvestris*) decayed by brown rot was investigated to det. any com. or scientific value. I contained 12.3% α-cellulose and 43.3% Klason lignin. The amts. of ether- and acetone-solubles were similar to that of fresh pine (II). MeO groups were split off by the prolonged decay. C and H detns. compared with values for Willstaetter lignin from II suggest an oxidation reaction as follows: $2(C_{20}\ H_{11}\ O_{3.5})n + 3n\ O > 2(C_{10}\ H_{11}\ O_5)n$. Oxidation of I with $PhNO_3$ and alkali gives a low yield of vanillin which indicates that the decay has attacked the vanillin-yielding group of the lignin. Alcoholysis of I gives a 48.9% yield of H_2O-sol., ether-insol. products compared with a yield of 20% for II. Sulfite digestions were carried out on I at pH 2 and 10.1. In the acid digestion most of the lignosulfonic acids can be pptd. from the spent liquor with 2–$C_{10}H_7NH_2$.HCl but in the alk. sulfite cook the ppt. amounts to less than half the lignin content of the wood. Analyses of the ppts. show high S and low MeO contents. The ratio S/OCH_3 is 1.67 for the acid sulfite cook ppt. The ratio N/S is also high, approaching 2.0. The lignosulfonic acids from I do not have tanning properties. I is easier to delignify by a sulfite cook than is fresh wood, but methylation of I with Me_2SO_4 and alkali causes an increase in MeO from 5.9% to 8.2% and prevents the acid sulfite cook practically completely. Methylation also inhibits the digestion of I by sulfate or NaOH liquors, but to a lesser extent than it inhibits the sulfite cook. Methylation of II inhibits its alk. digestion much more completely. The lignin pptd. from the black liquor by HCl from a NaOH cook of methylated I is highly methylated. This, together with the high O content of the C_6H_6–EtOH ext. of the wood and the high N/S ratio of the 2–$C_{10}H_7NH_2$ salt of the lignosulfonic acids indicate a high carboxyl content in II. 27 references. [Chem. Abs. V. 48, No. 15]

Narayanamurti, D., and George, Joseph (Forest Research Inst., Dehra Dun, India). The biochemistry of wood-rotting fungi. V. Enzymically liberated lignin and its applications. *Composite Wood* 1, 51–5 (1954); cf *C.A.* 47, 10844g.

Because it has been found that fungus-attacked sawdust could be molded under heat and pressure to give molded products of satisfactory strength and H_2O-resistance, a no. of fungus attacked woods are analyzed for Et_2O, Et–OH–C_6H_6, and hot H_2O extractives, pentosans, lignin, cellulose, and ash, with the following results (all in %): *Shorea robusta,* decayed by *Hexagonia sulcata,* 1.75, 9.17, 3.58, 6.47, 88.27, —, 0.5; by *Trametes cubensis,* 2.53, 13.02, 4.81, 10.56, 84.53, —, 1.12; *Pinus longifolia,* decayed by *Lenzites saepiaria,* 3.67, 9.30, 8.90, 5.74, 89.00, 0.57, 0.66; *Bombax malabaricum,* unidentified white rot, 0.35, 1.55, 8.17, 0.51, 30.00, 54.46, 2.30; *Canarium* sp., fungus unidentified, 1.20, 5.27, 4.38, 15.16, 32.90, 42.28, 1.25; *Acacia arabica,* by *Lenzites trabea,* 2.99, 9.51, 8.02, 8.84, 46.34, —, 0.67; bamboo, by *L. trabea,* 1.32, 3.95, 10.57, 19.82, 49.90, 41.37, 1.30. Because it is possible that the lignin is activated in the decaying process, *P. longifolia* shavings and sawdust are decayed by *L. saeparia* under controlled conditions for 8 and 12 months, resp., and analyzed as above. The results show that the extractives, probably by the liberation or depolymerization of some lignin, and the lignin content increase, whereas the cellulose and pentosan contents decrease.

Whereas the native lignin isolated from the sound wood has a MeO centent of 16.26%, that of the decayed wood has a MeO content of 10.01%, indicating a certain degradation of the lignin. The decayed wood can be molded either alone or with the addn. of some PhOH or cresol. The addn. of hemicellulose-rich material, such as date-seed powder, improves the hardboard formation. The results are given in a table. [Chem. Abs. V. 48, No. 16]

Wood Preservation

Becker, G. Recent research and development in wood preservation in Germany [with discussion]. *Rec. [3rd] Conv. Brit. Wood Pres. Ass. 1953* [1954?] (37–58).

Reviews literature on biological tests of preservatives, tests on leaching, penetration, effects of preservatives on timber strength, and reactions of preservatives with metals and lime, on research on methods of preservation and the detection of preservatives, and on developments in methods of application. [For. Abs. V. 15, No. 3]

Schempp, K. Necessary wood preservation measures in building construction and other fields. *Werkstoffe und Korrosion, Weinheim* 2 (2), 1951 (51–4).

An account of research done by the Deutsche Gesellaschaft für Holzforschung, and of modern preservation techniques. Includes a diagram showing 10 grades of wood protection as proposed by E. Giesecking. [For. Abs. V. 15, No. 3]

Plywood

Larsson, G., and Wastlund, G. Plywood as a material in constructional design. *Medd. Komm. Byggnadsforskn., Stockholm* No. 21, 1953. pp. 120. 126 refs. [Sw.e.]

The first section of the book deals with the strength characteristics of plywood and tests for their determination; the second (by G. Larsson only) deals with the cross-sectional design of beams with plywood webs, particular attention being paid to the strength and stability of these webs. [For. Abs. V. 15, No. 3]

Furniture Manufacture

Packing furniture with corrugated paper—dark streaks *Holztechnik,* Vol 34, No. 6, June 1954, p. 286 (in German).

If furniture is finished and then packed in corrugated paper before it is completely dry, there is a risk that dark streaks will develop in the part of the surface in contact with the paper. These can generally only be removed by scraping and complete refinishing may be necessary. The marks are caused at the places where the corrugated paper has been pressed on the surfaces; the solvent from the finish collects here and dissolves the adhesive out of the paper. This adhesive is slightly acid and it reacts with the tannin in the wood forming a dark stain. The effect is particularly serious on light oak furniture and when single furniture parts are stacked one on top of the other and separated by corrugated paper.

Marking can be avoided firstly by making sure that the finish is completely dry and then packing and arranging the parts carefully. If a piece has to be packed quickly it should be wrapped in a packaging material containing no glue. [F.D.C. Tech. Bul. V. 4, No. 23]

J. Starr. Finishes using leather as an ingredient. *Organic Finishing,* U.S.A., Vol. 15, No. 6, June 1954, pp. 12–3.

Leather finishes are usually produced by bonding natural or synthetic leathers to the surface.This is not altogether satisfactory, for leather is relatively expensive and because the bond may fail. There has therefore been considerable interest recently in a process which uses scrap leather dust to produce leather-type finishes which have adhesive properties as good as those of organic coatings.

The process involves dispersing the leather dust with an adhesive in a suitable liquid; the resulting mixture can be applied direct to the surface by brushing, spraying or dipping. If a leather-grain effect is required the coating material is first applied to a die which has been treated with a mould-release agent. When this is dry the surface to be finished is given one coat and while this is still wet the coated die is clamped on it. After about 30 min the die can be removed leaving the leather finish well bonded to the surface.

Several variations to the technique are suggested. [F.D.C. Tech. Bul. V. 4, No. 23]

D. Bullivant. The design of comfortable chairs. *Architectural Design,* Vol. 4 No. 8, August 1954, pp. 237–40.

This article is a summary of recommendations for a comfortable seat, which have been put forward by J. J. Keegan. Dr. Keegan has made an analysis of seating in relation to back symptoms based on a study of 3000 people in America as well as on a

special study of the alteration of the lumbar curve of the spine in sitting and standing positions.

The most important feature is the placing of a primary back support over the lower lumbar spine. The ideal angle between the trunk and thigh is 135° but it should not be less than 105°.

Three reclining chairs are illustrated and their design is criticized with reference to the height of the front of the seat, the slope, shape and depth of the seat, the angle of the backrest to the seat and the degree of lumbar support. [F.D.C. Tech. Bul. V. 4, No. 23]

Machining

A. H. Haycock. The cracking of wide bandsaws: part 1–3. *Wood*, Vol. 19 Nos. 7–9, July–September 1954, pp. 304–7, 358–40, 380–2.

One of the factors which cause cracking is fatigue in the metal and experiments have shown that the effect can be reduced if the metal is allowed frequent recovery periods. The author considers that there should be a minimum of six saws in use on any one machine and these should be used in strict rotation. The ideal arrangement is to have twelve saws for each machine—six in use and six resting. Metal fatigue is also increased by vibration, which may be caused by uneven pulley faces or poor tooth shape.

Care must be taken not to burn the steel when sharpening the saw; this causes a hardened skin to form on the surface of the steel and the minute cracks which develop in this skin will develop into large ones. Cracks in the back edge of the saw are generally due to fatigue, but they may be due to incorrect tensioning; it is important to roll the extreme back edge of the saw.

When brazing a saw it is important to apply sufficient solder and it is recommended that two strips of silver solder should be used. If the necessary equipment is not available, the most effective method of stopping the crack is to drill a slot about $\frac{1}{16}$in × $\frac{3}{16}$in at the head of the crack. This method cannot be used if the crack extends more than a sixth of the width of the saw.

A diagram and a description of a suitable clamp are given and the technique of welding is described in detail. The author recommends the use of a strip of steel cut from an old saw to fill the groove in the blade. After welding it is important not to move or knock the saw until the weld has been tempered. If no brazing oven or forge is available, this can be done by covering the hot blade with asbestos. The weld can then be cleaned off. [F.D.C. Tech. Bul. V. 4, No. 23]

Hard faced saw blades last 150 times longer before re-sharpening. *Aust. Timb. J.* 19 (9), 1953 (643).

For cutting a considerable quantity of Walnut, a 16-in. saw blade was faced with Cobalide 3 (an Australian-produced cobalt/-chromium/tungsten alloy). The method of facing and grinding is described. After facing, sharpening was done once a week instead of every 15 min. as previously. [For. Abs. V. 15, No. 3]

Thunell, B. Research and development in the field of sawmill engineering [in Sweden]. *Holz Roh- u. Werkstoff* 11 (11), 1953 (420–9).

Both frame- and circular-saw mills are found, the former consisting, as a rule, of one or more production lines each of ca. 25,000 cu.m. (converted) annual capacity. The latter are more diversely organized and produce timber of less accurate dimensions. There are in all, 8000 sawmills in Sweden with a total annual output of 5,600,000 cu.m. [For. Abs. V. 15, No. 3]

Chipboards

Stegmann, G. Development and manufacture of wood chipboards. *Holz-Zbl.* 80(23), 1954 (297–8). [G.]

Summary of the conference of the 'wood utilization (improvement)' section of the Deutsche Gesellschaft für Holzforschung (11 Feb. 1954, Brunswick), including papers on: reduction of swelling; chipboards resistant to fungi and termites; fireproof chipboards, and Japanese experience in chipboard manufacture. [For. Abs. V. 15, No. 3]

Waste Utilization

Anon. South's first slab concentration yard in operation in Alabama. *Paper Ind.* 36, no. 7: 685–6 (Oct., 1954).

The slab concentration yard of Clancy Forest Products, Inc., at Decatur, Ala. utilizes a slab debarker designed by the firm's president. The three 900-p.s.i. water jets of the debarker strike the bark surface of the slabs at a 30° angle, producing slabs that are bark free with no damage to the wood. The yard also has chipping and screening equipment; the recovery rate is one-half cord of chips/1000 feet of lumber. [Bul. Pap. Chem. V. 25, No. 3]

Moulding wood waste into salable products. *Wood and Wood Products*, U.S.A., Vol. 59, No. 7, July 1954, pp. 28–9, 45.

Salad bowls, bowling and croquet balls, toys, chair backs and toilet seats are now being moulded from wood particles and resin. Nearly any wood species or combination of species is suitable, the choice depending on the cost, availability and properties required in the moulded part. The size and shape of the wood particles which can be used are largely governed by the type of product to be moulded. Fine, uniform particles of 40–110 mesh will give smooth, hard surfaces suitable for painting and other finishing operations. Where the finish is not important, coarser wood particles of 8–40 mesh may be used.

Phenol formaldehyde resins are most commonly used because they have exceptionally good thermal flow properties, they are strong and water-resistant and harden quickly. Urea formaldehyde resins are used when water-resistance and durability are not important since they are cheaper and can be cured at lower temperatures than phenolic-resins. Melamine formaldehyde resins offer exceptional resistance to light and so can be used to produce lighter coloured mouldings, which have physical properties as good as those made with phenolic resins. [F.D.C. Tech. Bul. V. 4, No. 23]

Kurth, E. F. Utilization of barks. Proc. Sixth Pacific Northwest Ind. Waste Conf., Univ. Wash., March 18–19, 1954: 20–2.

The author discusses the available volume of bark in the United States; barking machines; the chemical and physical utilization, with particular reference to barks from Pacific Coast timbers and research in this field at the Oregon Forest Products Laboratory; Douglas-fir bark products; hardboard from slabwood without previous bark removal; agricultural uses of sawmill residues (soil conditioner and mulching); and the use of bark for paper specialties. [Bul. Pap. Chem. V. 25, No. 3]

Barking Machines

Ohlsen, B. Barking machines. *Transl. For. Prod. Lab., Can.* No. 59, 1953. pp. 10.

Gives some technical data on the following makes: (1) Anderson's, (2) Söderhamns Verkstader's transportable B12M, (3) Skoglund's type 12, (4) Sund's transportable BMB14P, (5) 'Mira' barker T212, and (6) 'Palmia'. [For Abs. V. 15, No. 3]

Hardwood Utilization

Lengyel, P. Utilization of hardwoods in the paper industry. *Papir- és Nyomdatechnika, Budapest* 4 (6/7), 1952 (46–52). From *Hung.tech. Abstr* 5 (2), 1953 (No. 93).

Tests have shown that hardwoods should be cooked to semichemical pulp or at least to part-digested chemical pulp. Beech, Poplar (white and Lombardy), Birch and Willow have been compared with Pine and the applicability of different pulping processes examined. The neutral semichemical sulphite and the kraft processes retain a larger % of pentosans in the pulp; for Poplar the strength properties of these pulps is increased owing to the fibre-to-fibre bonding by pentosans. [For. Abs. V. 15, No. 3]

Tebbe, Chas. L. Hardwood disposal—a pressing forestry problem. *Paper Trade J.* 138, no. 42:52 (Oct. 15, 1954).

The author announces that a survey is under way to determine the amount of timber available and other pertinent information in specific areas to disclose those areas where excess hardwood timber exists and should be removed. [Bul. Pap. Chem. V. 25, No. 3]

Vogel, John H. Industry effectively moving to ensure future wood supply. *Southern Pulp Paper Mfr.* 17, no. 10: 192, 194–5 (Oct. 1, 1954).

The expansion of the pulp and paper industry in meeting the ever-increasing demands of the country while still ensuring a future supply of raw material progressed in three major steps. The first change was from the use of cotton and linen rags to wood pulp, then from the stands of the northeastern states to the Lake States, and further to the stands in northwestern and southern regions, particularly southern pine, which had previously been considered unsuitable for pulp. Now in progress is a fourth extension of the industry, the trend toward the utilization of hardwoods, sawmill waste, and high-yield pulping processes. [Bul. Pap. Chem. V. 25, No. 3]

Wood Chemistry

Anderson, Ernest, Wise, Louis E., and Ratliff, Evelyn K. Note on the chemistry of the cambial zone of black spruce. Tappi 37, no. 10; 422–4 (Oct. 1954); *cf.* B.I.P.C. 17, 612.

A summative proximate analysis of the cambial zone of black spruce showed that the dry material was very high in extractives which contained much sucrose. The cambium also contained considerable protein, appreciable amounts of pectic material, but very little lignin and relatively small amounts of cellulose and hemicelluloses. That fraction of the zone which was most intensively studied, and which represented about 20% of its total dry weight, contained the cellulose and most of the initial lignin; it also retained an appreciable portion of the initial protein. The lignin to cellulose ratio in the cambium was much lower than that found even in young sprucewood. [Bul. Pap. Chem. V. 25, No. 3]

Wood Drying Committee Newsletter

Corrosion in Lumber Dry Kilns[1]

THE FOLLOWING TWO LETTERS on corrosion in lumber dry kilns were prepared by A. C. Knauss, Technologist, Forest Utilization Service, Pacific Northwest Forest Experiment Station, Portland, Oregon. The first letter was in reply to a request "as to the respective merits of various kinds of metals when subjected to conditions within dry kilns drying redwood, hemlock, and white fir." Knauss replied as follows:

"The problem of preventing corrosion of metal work in dry kilns used for seasoning lumber is a serious one, especially when high temperatures and humidities are used as a part of the schedule. Some species of wood are known to contain volatile acids and the problem has been more serious when drying them. The oaks, hemlock and redwood are prominent examples of such species.

"I have frequently heard discussions about preferred metals in a dry kiln to avoid corrosion. But I have not observed that choosing any of the metals you mention—aluminum, hot rolled black sheet metal (properly painted), hot rolled galvanized sheet and cooper bearing, hot rolled black or galvanized metal—is very effective in avoiding corrosion within dry kilns under conditions which favor corrosion. (It has seemed to me, however, that the galvanized metal was more susceptible to corrosion and should be avoided.)

Avoid Condensation

"It seems to me that corrosion of metals in dry kilns can best be minimized by construction and operation of the kiln to avoid condensation or collection of water on the metal. I have noticed that when water is allowed to collect on metal in a dry kiln, rapid corrosion results, whereas dry metal under the same use deteriorates very little. For example, when the steel rail in the track passing under the door is continuous from the loading platform into the kiln, the rapid loss of heat to the outside cools the rail just inside the door to such a point that vapor from the kiln atmosphere is condensed on it and corrosion takes place rapidly. When, however, the rail is split at the door and the rail portion inside the kiln is separate from the rail outside the kiln, the rail remains dry and corrosion develops only to a very minor degree.

"Similarly, corrosion develops on a fan shaft which is continuous through the wall of a kiln to the drive outside but I have not seen any arrangement whereby a fan shaft can be split at this point. Likewise, copper tubing conducting water into a kiln corrodes quickly if the water is cold and flows so rapidly that the pipe is cooled below the dew point to cause condensation on the tubing of the water vapor and any vapors coming from the wood. Flexible tubing between instrument case and bulb likewise corrodes just inside the kiln if the tubing is not insulated sufficiently to prevent cooling below the dew point.

"The metal caps or lids on roof vents are seldom insulation and therefore develop condensation easily, resulting in serious corrosion on the under side. Similarly, corrosion develops when water accumulates on the kiln floor and is whipped by the rotating fans onto metal ducts and other parts or when water is spewed from steam spray lines and strikes metal parts. Condensation dripping from a cold roof also is a source of water collecting on metal work.

"All this suggests the general principle that avoiding the presence of liquid water on metal parts in a kiln is a very effective means of minimizing corrosion in operation of a dry kiln. I think this can be done to a point where corrosion becomes a minor problem. In Germany, high temperature kilns were first made of sheet steel and when operating as superheated steam kilns, suffered severe corrosion. Coating with oil or heavy grease did not prove to be very practical because the oil disappeared too easily at the operating temperatures ranging from 212 degrees to 240 degrees. The Germans are now using sheet aluminum instead of sheet steel with better results. However, when I visited some installations in Europe last year I noticed some kilns were operating with wet bulb readings considerably below 212 degrees F. and the operators did not complain much about corrosion.

Steam Spraying

"Condensation of water on the kiln structure can also occur when kiln runs are started by using a large amount of steam spray to rapidly heat up the charge. In some extreme cases steaming (spraying only) has been used to heat the lumber and both lumber and kiln equipment become very wet. Such condensation is not necessary for the drying operation, does not benefit the lumber, and is avoided by a good kiln operator.

"Painting metal work with a good asphalt paint will greatly protect it from the corrosive effects, but repainting at frequent intervals is necessary to maintain good protection to the metal.

"Better use of insulation against heat and vapor loss is becoming increasingly important in our design of dry kilns. The German built kilns have reduced very materially the steam required for drying lumber by providing such insulation. At the same time this trend of design can be utilized to reduce condensation and corrosion hazards. I feel that in this country the time has arrived when dry kiln engineers should consider this point more seriously."

The second letter was written by Knauss after he had read Pat Williams, Jr.'s condensation in the January NEWS-DIGEST. The letter follows:

"I have just received and read with much interest the January 1954 FPRS issue of News Digest which you prepared, dealing with the subject of 'Corrosion in Dry Kilns.

Another Corrosion Cause

"My own observations on the performance of dry kiln structures and equipment, generally, agree with the information you have presented. There is an additional condition contributing strongly to kiln deterioration which you did not include, possibly for a very good reason. That is the deterioration which comes when water accumulates on material during operation of the kiln.

"I have noted that metal material, such as iron rails, metal on doors and fan shafts, instrument tubing, lids on roof vents, etc., corrodes badly if it is installed so that the heat loss causes condensation of water where it passes through the kiln wall or roof structure. Similar deterioration occurs when water from steam spray pipes or on the kiln floor is thrown against metal equipment.

"Painting with an asphalt paint to avoid wetting of the metal materially reduces the corrosion. I have observed that even unpainted metal in dry kilns does not corrode seriously when the kiln construction and operation are such that it remains dry. High humidity schedules, such as used for conditioning treatments to relieve casehardening often create a disadvantage for the operator because they create temporary surface condensation problems in the kiln equipment. I believe that our kiln equipment design must increasingly meet water condensation hazards as we plan higher humidity lumber drying conditions in our dry kilns.

"I shall be glad to hear what your observations relating to this phase of the problem might be. I am glad to see your contribution to News-Digest."

[1] Additional information on Corrosion in Lumber Dry Kilns appeared in the May 1954 issue of the Wood Drying Committee Newsletter. Copies are available free from the Executive Office, Forest Products Research Society, Box 2010, Madison 5, Wis.

FPRS News-Digest, Continued

(Continued from page 13-A)

Wert, vice-chairman; Tony Veazey, secretary-treasurer; and L. V. Brown, Harold Z. White, Robert E. Jones, and Herbert McKean, trustees.

Dr. Edward G. Locke, U. S. Forest Products Lab., addressed the meeting on "Fiber Products as a Factor in Utilization." "General Outlook for the Lumber Industry—Is it a Good Insurance Risk?" was the topic of John B. Grantham, Oregon Forest Products Laboratory. J. Kenneth Pearce, U. of Washington, spoke on "Bird-Dogging Overlooked Forest Materials."

The meeting closed with a tour of the sawmill and plant of the Cascade Lumber Co.

SHORT COURSES

Kiln Drying Course Planned At Forest Products Laboratory

A two-week training demonstration on kiln drying of wood will be held at the U. S. Forest Products Laboratory, Madison, Wis., March 28–April 8, according to an announcement by Raymond C. Rietz, chief of the Lab's division of timber physics. Enrollment will be limited to 35 men to assure individual attention, Rietz said.

Subjects to be covered include basic principles of air drying and kiln drying, types of dry kilns, kiln equipment, operation, tune-up, and moisture control during storage and production. Special emphasis will be given to improved kiln-drying methods that can significantly reduce kiln time and seasoning degrade.

The demonstration is planned so that no previous experience is necessary for a complete understanding of the subject, according to E. F. Rasmussen, dry-kiln research engineer in charge. Men attending will operate kilns under the supervision of laboratory specialists. They will also work practical problems on the use of balances, scales, ovens, moisture meters, thermometers, recording-controlling instruments, and other dry-kiln equipment.

The course fee is $200 per man, which covers laboratory expenses for the actual time of the specialists in charge, and the costs of materials and publications used as texts. Further information is available from the Laboratory at Madison, Wis.

Penn State Plans Grading Course

Applications are being accepted for the third annual course in hardwood lumber grading at Pennsylvania State University March 14–18. The course will cover grading, inspection, thicknesses, measurement, manufacture, and related topics. Registration blanks and additional information may be obtained from Prof. Orvel A. Schmidt, Penn State U., State College, Pa.

Three Industry Short Courses To Be Held at North Carolina

Three industry short courses are planned in March and April at the School of Forestry, North Carolina State College, Raleigh.

A small sawmill operators course will be held March 28–April 1, in cooperation with the N. C. Division of Forestry, Southeastern Forest Exp. Sta., and N. C. Forestry Assoc. Fee for the course is $35.

April 4–8 are dates of a hardwood lumber grading course, with a $35 fee. Cooperating will be the Dept. of Industrial Engineering, National Hardwood Lumber Assoc., and the Southeastern Station.

Operations with and maintenance of carbide tools is the subject of a course scheduled April 11–15. The FPRS Wood Machining Committee and Southern Furniture Manufacturers Assoc. will cooperate in this course, which has a fee of $40.

TECO Glue School Set for March 14–18

Training in modern glues and gluing techniques will be given in a short course March 14–18 at the laboratory of Timber Engineering Company, Washington, D. C. Aim of the course is to help industry representatives improve their products, increase production, save time, material, and labor, and otherwise operate more profitably.

Lectures and demonstrations will

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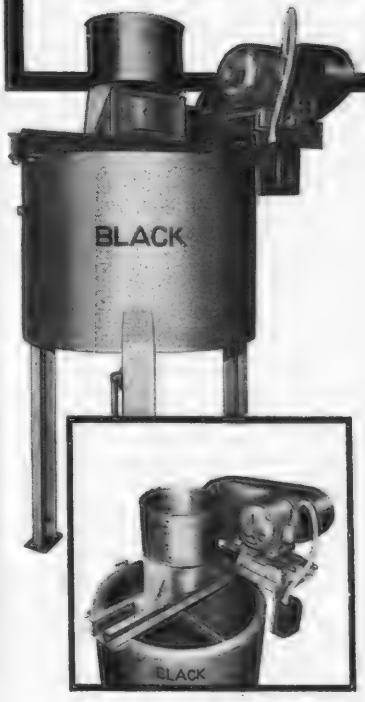
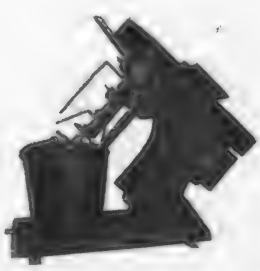


The Black Brothers stationary cold glue mixers are made in a full range of capacities from 10 to 500 gallons. They are the result of expert engineering combined with years of practical experience in glue equipment manufacturing. Their many features include: (1) Sifter for glue powder (2) *Double agitators which give a beating action resulting in the smoothest possible mixture in the least possible time* . . . see close-up on left (3) Pressure lubrication (4) Cut steel gears . . . hardened and lapped (5) Large quick-acting valve at bottom. Optional equipment includes (1) water jacket (2) variable speed drive. For full information write today for Bulletin 11-1.



The Black Brothers portable motor driven cold glue mixer is made in 2, 5, 7½, and 15 gallon sizes. It has a number of exclusive Black Brothers features such as glue powder sifter, two-way agitation, and specially shaped flat paddles to give a beating action to the agitator. In addition this mixer has a hinged arm that swings up to allow the pail to be inserted or removed. Write for Supplement to Bulletin 11-1.

"If it Is Gluing Equipment—We Have It"

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cover the various types of glues and their uses, factors affecting strength of glue lines, curing methods, various testing methods, quality control, trouble shooting, and other important procedures.

Complete information, including course outlines and application forms, may be obtained from the Timber Engineering Co., 1319—18th St. N. W., Washington 6, D. C.

Syracuse College Schedules Quality Control and Grading Courses

"Statistical methods of quality control are an invaluable engineering tool to wood industries," said Dr. Aubrey E. Wylie in announcing a short course in quality control to be held April 12–16 at State University College of Forestry, Syracuse, N. Y.

The course will be held simultaneously with a course in hardwood lumber grading. Fees for the quality control and grading courses are $50 and $35, respectively.

Limited to 15 students, the quality control course will include a study of the quality problem, basis of control, control charts, acceptance sampling experimentation and problem analysis, and practice of quality control.

The National Hardwood Lumber Assoc. Rule Book will be a basic text for the grading course. The teaching staff will include Floyd T. Potter, chief inspector for Northeast section, NHLA; and the following forestry college faculty members: John M. Yavorsky, Robert J. Hoyle, Jr., Robert A. Zabel, and John B. Simeone.

Further information and application blanks may be obtained from Prof. Russell E. Deckert, State U. College of Forestry, Syracuse 10, N. Y.

Wear Your FPRS Badge Proudly

This attractive green and gold FPRS lapel pin is now available. It will identify you as an active supporter of wood industry research and progress. Simply send 75 cents to Executive Secretary, P. O. Drawer 2010, University Station, Madison 5, Wis. or send $1 and also receive framable FPRS wall certificate.

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Dr. Gerry Dr. Brother

NAMES IN THE NEWS

Dr. Eloise Gerry Retires From Forest Products Lab

Dr. Eloise Gerry, one of the first women in the U. S. to make a career of forest products research, retired January 31 after more than 44 years' service at the U. S. Forest Products Laboratory, Madison, Wis.

Dr. Gerry was the only woman member of the original staff that opened the Laboratory in 1910. Her work and the many technical publications she has authored have gained her international recognition.

Her research on the physiological and structural anatomy of wood has resulted in significant data that benefited the entire industry. She reports her most interesting period of research started in 1915 when she pioneered microscopical investigations of the turpentine pines of the South. The results of her studies were later summarized in a Naval Stores Handbook which became the "bible" of the industry and served as a stepping-stone to present-day advances.

Dr. Gerry has also conducted fundamental studies of wood structure, such as the physiology of parenchyma cells, wound reactions, and the transformation of sapwood into heartwood. In recent years she has become widely known as a specialist on foreign woods.

Turner Has New Position

H. Dale Turner has joined the research and development dept. of Masonite Corp., Ukiah, Calif. He was formerly with Olin Industries, Elgin, Ill.

Allegretti Promoted

J. J. Allegretti has been promoted to manager of the Product Development and Market Research Dept. of the Masonite Corp., with headquarters at 111 W. Washington St., Chicago.

G. H. Brother Joins Union Lumber Co.

Dr. George H. Brother has joined the research staff of the Noyo Chemical and Fiber Division of Union Lumber Co., Fort Bragg, Calif.

A former employee of the U. S. Dept. of Agriculture, Dr. Brother also worked 20 years in industrial research on fatty acids, plastics, leather, and leather finishes.

Dr. Brother received B. S. and M. A. degrees from the University of Nebraska, and Ph. D. from the University of Toronto. He was formerly on the staff of Arthur D. Little, Inc., and a Fellow at Mellon Institute.

R. C. Flom Promoted

Russell C. Flom has been named assistant administrator of the Business and Defense Services Administration, Dept. of Commerce. Flom, on leave from his position as sales director for the Marathon Corp., has been director of the BDSA Forest Products Division since September.

Vickery Joins API Staff

Windell W. Vickery has been appointed forest products marketing specialist of the extension service at Alabama Polytechnic Institute, it is announced by Ivan R. Martin, A.P.I. extension forester.

Vickery's new duties will include keeping sawmillers and farmers appraised of markets for lower grade hardwoods, promoting the use of low grade hardwood by industry, and interesting possible new industries in locating in the state.

A graduate of A. P. I., Vickery previously was forester for Southern Timber Management Service and did U. S. F. S. cooperative timber sales work in Arizona. He is secy.-treas. of the F-G-A Section of FPRS.

Dr. Henry K. Benson Dies; Washington Wood Chemist

Dr. Henry K. Benson, emeritus professor of chemical engineering at the University of Washington, died in Seattle Sept. 27. Dr. Benson retired as chairman of the Dept. of Chemistry and Chemical Engineering in 1947, after 43 years at the University.

Dr. Benson earned B. A. and M. A. degrees at Franklin and Marshall College, and Ph. D. at Columbia University. In 1912 he became interested in the possibilities of wood utilization by destructive distillation and charcoal production. He was commercial agent for the U. S. Dept. of Commerce in 1914, publishing the results of his studies in a bulletin: "By-Products of the Lumber Industry."

Serving as chairman of the Division

of Chemistry and Chemical Technology of the National Research Council in 1931–32, Dr. Benson authored a booklet on "Chemical Utilization of Wood." During his career he wrote more than 100 papers concerned with wood chemistry, chemical engineering, and related subjects. In recent years several of his papers dealt with pulping of woods by ammonium bisulfite solutions and with various aspects of sulfite spent liquor.

Finley Heads New Program

William C. Finley has joined the staff of Battelle Institute, Columbus, Ohio, where he will head a program to expand research facilities for the forest products and wood-using industries. Prior to joining Battelle, Finley was with the American Walnut Manufacturers Assoc., the National Cedar Chest Assoc., the Veneer Assoc., and Aromatic Red Cedar Assoc. He has also served as consultant to several state and regional groups.

Baxter D. Whitney & Son Names Two Sales Representatives

Appointment of two representatives has been announced by Baxter D. Whitney & Son, Inc., Winchendon, Mass., woodworking machinery builders. They are Claude S. Sutton, Greensboro, N. C., covering Virginia and the Carolinas; and C. H. Cowan, Memphis, Tenn., Tennessee and upper Kentucky.

Sutton was southern representative for the Whitney company from 1934 to 1950 and Cowan also was formerly a Whitney representative.

New Consulting Service

Monie S. Hudson has announced opening of a consulting service and laboratory, specializing in problems of the wood and wood products industries. His office address is Box 2451, Spartansburg, S. C.

Cohn Elected President Of Radio Receptor Company

Election of Hugo Cohn as president has been announced by the Radio Receptor Co., Inc. He succeeds Ludwig Arnson, who is retiring after serving as president for 31 years. Mr. Arnson will continue as a director and consultant. Harold R. Zeamans has been elected secretary-treasurer of the firm.

Mr. Cohn, who formerly was executive vice-president, has been an officer of the company since its founding in 1922. They manufacture electronic equipment for communications, radar and navigational applications, selenium rectifiers, germanium diodes and transitors, and dielectric heating equipment.

Louis Heads Bartrev Sales

Appointment of L. R. Louis as vice-president in charge of sales of Bramco, Inc., a new firm, has been announced by Bartrev, Ltd., producers of the Bartrev continuous press. Louis' appointment is part of a new alignment of Bartrev's activities in the U. S. and Canada.

Aries Fiberboard Corp. will continue to serve as consultants on technical aspects of particle board manufacture by the Bartrev process, but are withdrawing from sales activities. Louis was formerly sales director for Aries.

Goddard Named Dept. Head

Maurice K. Goddard, Director of the School of Forestry, Penn State University, has been named Secretary of the Dept. of Forests and Waters by Pennsylvania Governor George M. Leader.

Complete Service On Wood Preservatives!

TECHNICAL COUNSEL

A full staff of specialists with years of experience and complete laboratory facilities, ready to assist in every way.

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Most satisfactory and permanent of all wood preservatives against decay, fungi, termites and other wood boring insects.

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FPRS News-Digest, Continued

NEW PUBLICATIONS

A National Standard for Grading Canadian Lumber. J. H. Jenkins. Reprint from Canadian Lumberman. Forest Products Laboratories of Canada, Ottawa. Outline of steps being taken to establish uniform grading standards.

Lumber and Pickets. G. W. Andrews. Reprint from Timber of Canada. Forest Products Laboratories of Canada, Ottawa. A comparison of recovery of waste material by two edging methods. One of a series of reports of research to investigate methods of increasing sawmill efficiency and waste utilization.

Deterioration of Materials—Causes and Preventive Techniques. Edited by Glenn A. Greathouse and Carl J. Wessel. 835 pages. Reinhold Publishing Corp. Price $12. Analyzes deterioration problems and surveys preservative techniques for such materials as wood, metals, textiles, paints, etc. Part I deals with basic causative agents, Part II action of these agents on various materials, Part III protection of certain important equipment assemblies, and Part IV special aspects of preservation. Compiled by 24 specialist contributors, the book contains 255 illustrations, nearly 1500 documentary references.

Wood Preservation Statistics 1953. Gordon D. Merrick. Forest Service, U. S. Dept. of Agriculture. Reprint from AWPA Proceedings, 1954. Presents statistics of wood-preserving industry for calendar year 1953, compiled by Forest Service in cooperation with the American Wood-Preservers Assoc. Based on data from all wood-preserving plants of record maintaining permanent or non-pressure (open tank) equipment.

Sheathing Board from Ponderosa Pine Mill Residues. Report No. L-4, Oregon Forest Products Laboratory, Corvallis. Results of a study of the practicability of making low-cost sheathing panels from ponderosa pine mill residues. The work included an illustration of erection costs of a plant to manufacture commercial particle-board panels, manufacturing costs, probable returns, and other factors to use in evaluating suitability of such a process to a particular situation.

Construction Review. Supt. of Documents, Govt. Printing Office, Washington 25, D. C. Annual subscription $3 domestic, $4 foreign. This new joint monthly publication of the Departments of Commerce and Labor replaces two former publications, *Construction* and *Construction and Building Materials*. The publication contains major statistical series compiled by the Federal Government and some private sources in the construction field, including new construction volume, materials production, housing starts, contract awards, labor requirements, forecasts, cost indexes, materials prices, and related facts.

Design of Experiments, Parts I and II. H. Grinsfelder. Reprint from Resin Review, Rohm & Haas Co., Philadelphia, Pa. A discussion of statistical quality control techniques applicable to many industries.

Sawmills in Finland Use New-Type Metal Detectors. Eero Yrjonen and L. W. Crandall. Reprint No. 243, University of Wisconsin Engineering Experiment Sta. Discusses new type portable metal detector used to inspect wood scrap on its way to a chipper. Reports on another new model used for checking saw logs.

The following publications are available from the U. S. Forest Products Laboratory, Madison, Wis.

Wood at low temperatures. Kenneth H. Boller. Reprint from Modern Packaging. Discussion of the effect of extremely low temperatures on wood and wood containers.

List of Publications on The Seasoning of Wood. No. 446. October 1954.

List of Publications on Glue, Glued Products, and Veneer. No. 513. December 1954.

Preservation of Timber by the Steeping Process. No. 621. October 1954. Report of relatively inexpensive preservation method, including kinds of preservatives, method of treatment, cost, and effectiveness.

Structural Values of Old Lumber. Lyman W. Wood. No. 2009. November 1954. Discusses effects of age on structural lumber, evaluation considerations, and re-use of structural lumber.

Synthetic Resin Glues. No. 1336. Rev. November 1954. Summary of the general properties and use characteristics of each of the principal types of synthetic-resin wood-working glues. Also reviews the gluing processes used with these glues.

Utilization of Hardwoods. J. A. Hall. Reprint from APA 1954 Pulpwood Annual. Discusses increased use of hardwoods in pulp and paper industry, and problems now limiting such use. Various hardwood pulping processes and uses for products of each process are described.

List of Dry-Kiln Companies, Engineers, and Consultants in the United States. No. 1031. Rev. Feb. 1955.

Tests of Decay Resistance of Four Western Pole Species. No. 2006. October 1954. Comparison of the natural decay resistance of heartwood of western red-cedar, western larch, Douglas-fir, and lodgepole pine. Accelerated decay tests were made on samples from pole-size trees of these species growing in the Inland Empire.

Condensation and Decay Prevention under Basementless Houses. No. 2010. November 1954.

Use of Bleached Cold Soda Pulps from Certain Mixtures of Latin-American Hardwoods in Newsprint. No. 2013. December 1954.

FPRS SCOREBOARD
by Bob Smith

As of February 10, the Society has reached a new high of 2,705 members in good standing! Efforts by Section membership chairmen and officers plus executive office correspondence paid off in January to a new high of 91 members gained in the biggest month in FPRS' history.

There are six Section meetings plus the National Meeting scheduled for the first half of 1955. These meetings are excellent opportunities for you to invite your friends to attend and get acquainted with the aims and benefits of the FPRS.

Don't forget that the Sections with the most new members gained percentage-wise during the 1955 fiscal year (April 1, 1954–March 31, 1955) will receive suitable recognition at the National Meeting at Seattle in June.

Individual members can help their Sections into the winning class by sending names and addresses of prospects to me. I will be glad to write personal letters to your candidates.

Glancing at the table below, the Inland Empire Section is still leading the field in membership growth on a weighted percentage basis, but how about 2nd and 3rd places?

FPRS TEAM STANDINGS

	Members 1953	Members 2/10/55	Wgtd. Avg.
Inland Emp.	44	70	.534
East Canada	129	175	.338
No. Calif.	93	125	.336
Northeast	405	504	.242
Pac. N'west	299	361	.202
Midwest	306	368	.199
Ohio Valley	82	98	.190
Upper Miss.	80	95	.187
Great Lakes	167	195	.162
Pac. S'west	48	55	.198
Car.–Chesapeake	204	231	.127
Mid-South	140	156	.107
Fla.–Ga.–Ala.	86	92	.065
Foreign	193	180	---
Totals	2,276	2,705	.211

FPRS News-Digest, Continued

Room Air Cleaner

A small, portable machine which removes dust, smoke, pollen, and some types of bacteria from the air in a room is being applied to a variety of industries, according to Raytheon Manufacturing Co., Waltham, Mass. Developed for the relief of sufferers from hay fever and other allergies, the manufacturers report the "micronaire" unit is adaptable to operations requiring a dust-free atmosphere, such as painting, lacquering, and finishing. A common application is in the business world for removal of smoke and stale air in conference rooms and offices.

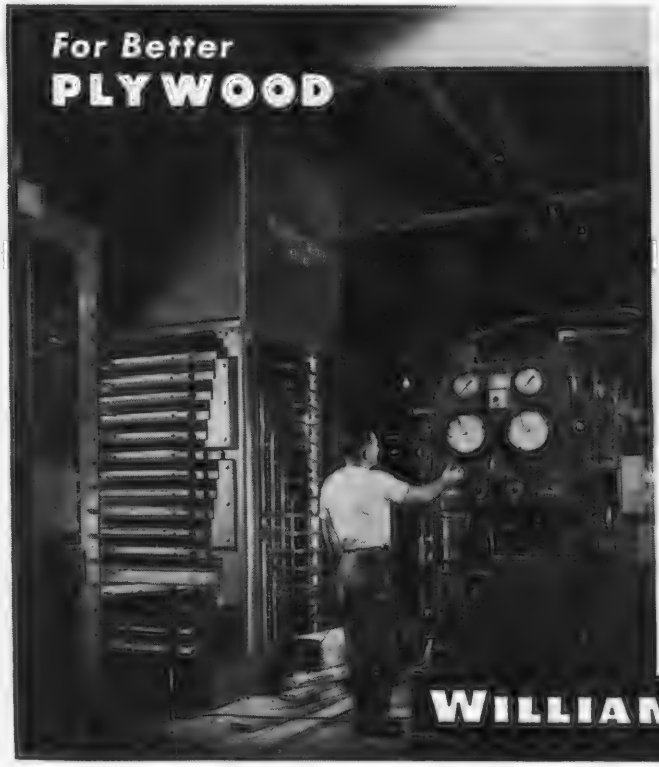
Bulletin on Reducing Bleeding

A technical bulletin on bleeding of pentachlorphenol-petroleum solutions from pressure-treated wood and how to reduce or prevent this nuisance is available from Chapman Chemical Co., Box 138, Memphis 1, Tenn. Tests reported in the bulletin, Technical Newsletter No. 14, indicate trapped air in the interior of the wood is primarily responsible for such bleeding. Gradual escape of the air after treatment forces the preservative to the surface. A method is recommended to reduce bleeding after treatment by a standard empty-cell schedule, and suggested schedules are given for using this method on various species, sizes, and forms of seasoned wood.

Sacking Scale

Problems in packaging their "Hardwood Nuggets" are reported solved by Nickey Brothers Co. of Memphis, Tenn., with the installation of a model 2225 sacking scale made by the Exact Weight Scale Co. of Columbus, Ohio.

The nuggets consist of highly compressed hardwood waste and are marketed for uses similar to charcoal. They are packaged in 10- and 20-pound bags at low cost with the new scale, which permits one man to both fill and weigh the bags in one operation. Raw material for the nuggets is obtained from wastes from Nickey Brothers' mill producing oak flooring and dimension stocks.



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MOLINE, ILLINOIS

FPRS News-Digest, Continued

Commerce Department Publishes New Product Idea Booklet

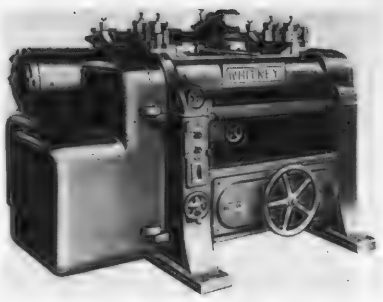
"Developing and Selling New Products" is the title of a how-to-do-it booklet recently revised by the U. S. Department of Commerce and scheduled for February publication. First published in 1949, the booklet aids manufacturers in developing and marketing new products.

The new edition tells how to locate new product ideas, select products which sell, and design, develop, name, package, and market the product. First-hand experiences are given of 100 firms successful in developing and selling new products.

Further information on the booklet may be obtained from field offices of the Dept. of Commerce.

Single Surface Planer

Introduction of a new six-roll single surface planer has been announced by Baxter D. Whitney & Son, Inc., Winchendon, Mass. It is designed for rough or finish planing at fast feeds, and is reported to give an accurate, high quality finish. New features include center table adjustment and integral construction of frame, wedges, and sash which houses the upper rolls and cutterhead. Standard equipment includes friction break on the cutterhead, 7-inch diameter sectional infeed rolls, back pressure bar with central adjustment, motor raising and lowering of bed.



New Woodwaste Resins

Two new woodwaste resins for fabrication of sawdust or wood chips into hardboards are reported by American Cyanamid Co. The binders, PDL 1-1969 and PDL 1-1970, are claimed to give good flexural strength and minimum swelling from water absorption, while imparting no color to the board. PDL 1-1969 is a melamine-urea formaldehyde type and PDL 1-1970 is an unmodified urea-formaldehyde resin.

Magnetic Pulley

Threefold benefits are derived from the installation of permanent non-electric magnets, according to Rock Island Millwork Co., Rock Island, Ill. The magnets afford protection against fire hazard, machinery damage, and product contamination resulting from tramp iron in the production line. A product of Eriez Manufacturing Co., Erie, Pa., the magnetic pulley was installed as the head pulley on a belt conveyor carrying wood scrap to the hammermill and pulverizer at the Rock Island plant. In operation, all wood material falls free on reaching the pulley. Stray pieces of metal are held by the magnet until the return of the belt has carried them beyond the point of contact with the pulley, where the metal falls automatically into a container.

Handling and disposal expense of waste wood can be cut as much as 75% by reducing it to chips in a Williams Hog. If handled manually, one man alone can move as much tonnage as three men could handle if scrap is in long strips or awkward shaped pieces. If handled automatically, top efficiency can be obtained only if wood is first reduced to chips.

In chip form, waste wood produces the greatest heat value. Unhogged waste cannot burn evenly because jumbled distribution of small and large pieces restricts air flow, smothers the fire, creates excessive smoke. Hogged wood chips control passage of air for even and complete combustion, yield more BTU's.

Savings in a few months will pay for an automatic installation for conveying wood waste to stoker or boiler.

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Employment Wanted

No. 242—Graduate of Pennsylvania State University in 1949 with a B. S. in General Forestry seeks position in logging, field work, or production. Has had experience as a civil engineer, office and design engineer, millwork foreman, and forester. Currently located in the Midwest, would be willing to locate elsewhere. Age 30. Married.

No. 243—Graduate forester currently employed as Assistant Superintendent of hardwood mill in Midwest, desires position with larger company. Thoroughly experienced in all phases of woodland management, logging, sawmilling, and marketing of hardwood lumber. Now available.

Positions Offered

No. E 162—Public Research Laboratory in South has openings for one or more qualified men to carry out investigations in the field of wood utilization. Applicants should desirably possess a maximum of the following: Advanced degree, valid research experience, initiative, versatility, practical experience in harvesting, manufacturing and processing of wood and the ability to effectively work with private industry.

No. E 163—Large midwest manufacturer of sawmill machinery and heavy equipment seeks top notch designer of woodworking machinery to add to its engineering staff. Send particulars to FPRS office who will forward same to manufacturer.

HELPFUL HINTS

Speeding Slow-Setting Glues

Slow setting of glue joints at the clamp carrier, when using animal glue, can often be accelerated by providing some means of exhausting damp air from the floor area beneath the clamps. At room temperature and low relative humidity (35 to 50 per cent) joints should be set up sufficiently to permit removal of the clamps within 30 to 45 minutes. Full cure of the glue joints requires from 12 to 36 hours.—*The Wood-Worker.*

Glue Storage

When a resin or casein glue is mixed according to directions and has the appearance of a sawdust-water mixture, the glue is definitely over-age and is worthless as an adhesive. Normally even fresh casin glue may become dry in appearance shortly after stirring it into water. After ten to thirty minutes, however, the mix becomes fluid and completely satisfactory for use. To insure good storage life, both casein and resin powders should be kept under cool, dry conditions. — *Perkins Glue Line.*

Safety Is Everybody's Job

The more we study the safety problem, the more we see that success in safety is the product of *an environment which emphasizes individual responsibility—exercised at all times and at all levels.* The feeling for safety must permeate the organization from top to bottom.—Crawford H. Greenwalt, President, E. I. DuPont de Nemours & Co.

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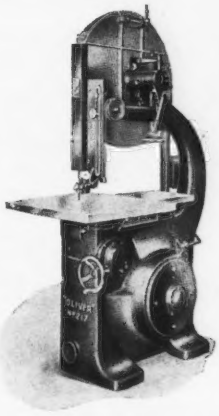

Has ring-disk wheels—run true and steady at all speeds. Positive brakes for utmost safety. Table tilts 45° to right, 10° to left—tilting device immersed in oil for accuracy. Takes 15" under guide, 29¼" between saw and column. Write today for Bulletin No. 217-D.

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Forestry and Wood Products Books Available Through FPRS

TEXTBOOK OF WOOD TECHNOLOGY — Vol. I — **Brown, Panshin and Forsaith.** American Forestry Series. 626 pp., 6 x 9 illus. (1949). **$7.50,** to FPRS members, **$6.75.**

TEXTBOOK OF WOOD TECHNOLOGY — Vol. II — **Brown, Panshin and Forsaith.** American Forestry Series. 761 pp., 6 x 9 illus. (1952). **$10.00,** to FPRS members, **$9.00.**

THE MANAGEMENT OF FARM WOODLANDS — Guise. American Forestry Series. 356 pp. 6 x 9, 82 illus. (1950). **$5.00,** to FPRS members, **$4.50.**

WOOD PRESERVATION—new second edition—**Hunt and Garratt.** American Forestry Series. 405 pp., 6 x 9 illus. (1953). **$7.50,** to FPRS members, **$6.75.**

FOREST INFLUENCES—Kittredge. American Forestry Series. 386 pp., 6 x 9, 24 illus. (1948). **$6.00,** to FPRS members, **$5.40.**

PLYWOOD—Meyer. Tells what it is, what it does. 250 pp., 6 x 9 illus., (1947). **$4.50,** to FPRS members, **$4.00.**

FOREST PRODUCTS, THEIR SOURCES, PRODUCTION, AND UTILIZATION. Panshin, Harrar, Baker, and Proctor. American Forestry Series. 549 pp., 6 x 9, 114 illus. (1950). **$6.50,** to FPRS members, **$5.85.**

FORESTRY AND ITS CAREER OPPORTUNITIES—Shirley. American Forestry Series. 467 pp. 6 x 9, 118 illus. (1952). **$6.50,** to FPRS members, **$5.85.**

HARVESTING TIMBER CROPS—Wackerman. American Forestry Series. 437 pp., 6 x 9, 183 illus. (1949). **$6.00,** to FPRS members, **$5.40.**

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WILEY BOOKS
On Forestry and Wood Products

FOREST PROTECTION, Second Edition

By Ralph C. Hawley, Yale University; and Paul W. Stickel, University of Massachusetts. A special study of the sources of injury to the forest. Gives you a well balanced treatment of the entire problem of forest protection in relation to the development of the forests. *1948. 355 pages. $5.00.* **To FPRS members, $4.50.**

MODERN TIMBER DESIGN

By Howard J. Hansen, Howard Hansen Inc. This book discusses all types of joints, glued laminated members, and plywood. Suggested working stresses are thoroughly discussed. Ample explanation of design procedures. *1948. 312 pages. $6.00.* **To FPRS members, $5.40.**

FOREST PRODUCTS

By Nelson C. Brown, formerly of Syracuse University. Discusses in detail the harvesting, processing, and marketing of materials other than lumber, including the prinicipal derivatives, extractives, and incidental products in the United States and Canada. *1950. 399 pages. $6.00* **To FPRS members, $5.40.**

LOGGING

By Nelson C. Brown. Offers a complete discussion of the logging industry, analyzing the principles and methods of harvesting timber in the United States and Canada. A comprehensive summary of regional logging methods is included. *1949. 418 pages. $6.00.* **To FPRS members, $5.40.**

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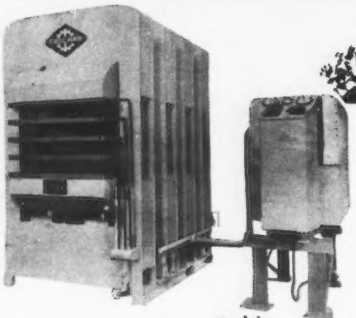
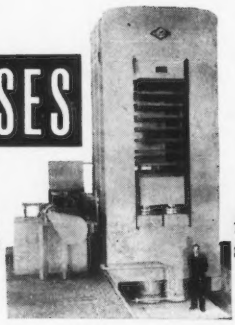
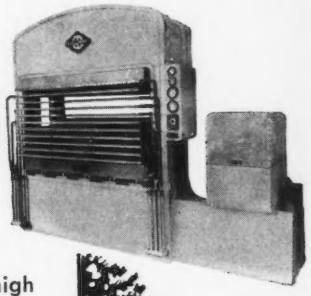




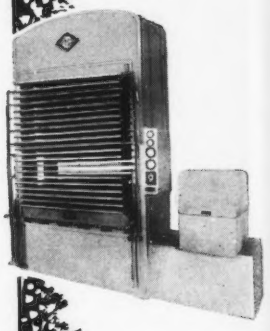


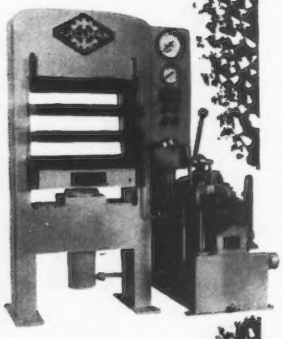
Fjellman Hydraulic Veneer Presses are the high standard for the woodworking industry. Internationally known for precision craftsmanship, these rugged presses bring new economy to American plywood processors—price and production-wise. Side or end loading; use high or low pressure steam. No special footings for 1 to 5 opening presses. Complete range of sizes from 12" x 12" to 8' x 19' and openings from 1 to 20.

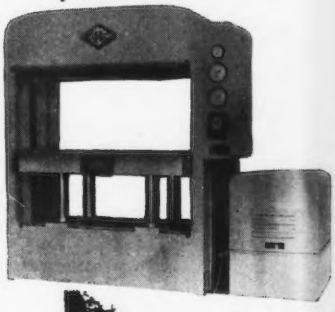
Fjellman presses are steel-frame construction for greatest rigidity, minimum yield, and light floor loading.

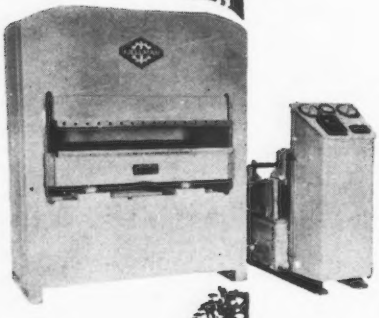
Platens are of Swedish firebox carbon steel, polished and ground for fine product finish. Parallel guides insure accurate closing and alignment under pressures to 2000 PSI.

Now also available with American instruments and pumps. Built according to S.A.E. specifications for quick, easy and economical maintenance.









FJELLMAN AMERICAN INC.

105 REPUBLIC AVENUE

JOLIET, ILLINOIS

MAILING ADDRESS:

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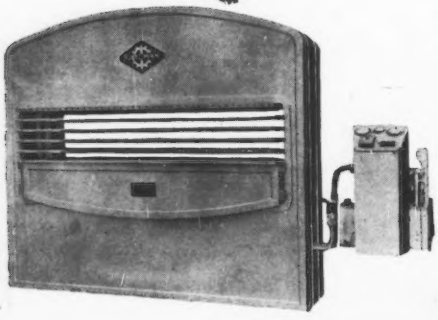

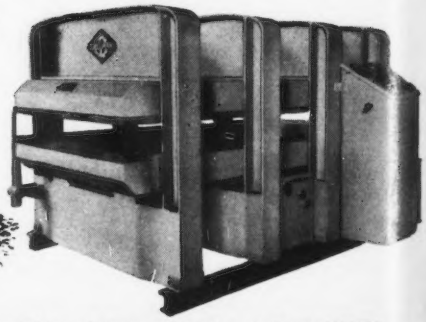

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